SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

The JOURNAL of the FEDERATION OF SEWAGE WORKS ASSOCIATIONS

Special Features

Chicago Air Diffusion Studies—Anderson

Boston Sewage Works—Kennison

Oxygen Utilization by Activated Sludge—Dawson and Jenkins

Industrial Waste Regulations—Washington Control Commission

Poultry Dressing Wastes—Heukelekian, et al.; Porges

APRIL, 1950—VOL. 22, No. 4

Make Plans to Attend—

TWENTY-THIRD ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

IN CONJUNCTION WITH

MARYLAND-DELAWARE WATER AND SEWERAGE ASSOCIATION (SEWAGE WORKS SECTION)

AND

FEDERAL SEWAGE RESEARCH ASSOCIATION

STATLER HOTEL

WASHINGTON, D. C.

October 9-12, 1950

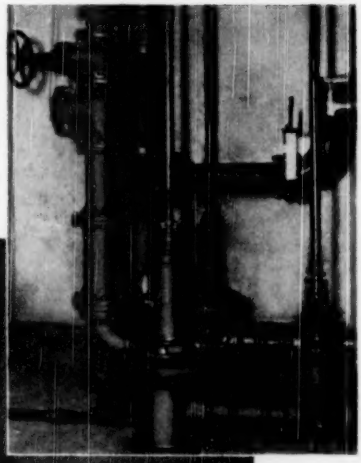
FEDERATION OF SEWAGE WORKS ASSOCIATIONS

323 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

CLOG-PROOF

•

RELIABLE



There's no substitute for The "Chicago"

FLUSH-KLEEN

Sewage Ejector of Proved Performance

"Flush-Kleens" are absolutely clog-proof . . . the impellers handle nothing but strained sewage, minimizing wear and maintaining pump balance. They need no manual attention other than lubrication and inspection. No labor is needed to dis-assemble and clean. Not just another practically non-clog pump—"Flush-Kleens" are *positively* clog-proof.

Look at These Long-established Facts

- "Flush-Kleens" are the only absolutely clog-proof sewage pumps; impellers are not required to pass any solids.
- The "Flush-Kleen" will pump anything that will pass through the pipe regardless of type or quantity of material.
- "Flush-Kleen" selection is not limited to a narrow pumping range to prevent dynamic unbalance of the impeller and consequent shaft and bearing failure.
- "Flush-Kleen" versatility and flexibility of operation make selection of the proper unit simple for small stations where accurate capacity and head figures are often not available.

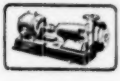
Write for further information and test data on Chicago Pump Company "Flush-Kleen" Sewage Ejectors.

CHICAGO PUMP COMPANY

SEWAGE EQUIPMENT DIVISION

2300 WOLFRAM STREET — **CHICAGO 18, ILLINOIS**

Flush Kleen, Scru-Peller, Plunger Horizontal and Vertical Non-Clogs Water Seal Pumping Units, Samplers.



Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

PRESIDENT

A. H. Niles
Engineer-Superintendent
Division of Sewage Disposal
Bay View Park
Toledo 11, Ohio

VICE-PRESIDENT

Ralph E. Fuhrman, Supt.
District of Columbia Sewage Treatment Plant
5000 Overlook Ave., S.W.
Washington 20, D. C.

TREASURER

W. W. DeBerard
City Engineer
402 City Hall
Chicago, Illinois

EXECUTIVE SECRETARY-EDITOR

W. H. Wisely
325 Illinois Building
Champaign, Illinois

ADVISORY EDITOR

F. W. Mohlman
Director of Laboratories
The Sanitary District of Chicago
910 S. Michigan Ave.
Chicago, Illinois

DIRECTORS

Alabama: R. C. Barton (1951)
Argentina: E. B. Besselievre (1943)*
Arizona: Harold Yost (1952)
Arkansas: B. W. Dees (1952)
California: Richard D. Pomeroy (1950)
Canada: William Storrie (1952)
Central States: George Martin (1951)
Dakota: Roy G. Spieker (1949)*
Federal: Lawrence M. Fisher (1950)
Florida: B. F. Borden (1950)
Georgia: Gilbert R. Frith (1950)
Inst. San. Eng. (Eng.): G. S. McDonald (1950)
Inst. Sew. Pur. (Eng.): W. F. Freeborn (1950)
Iowa: John L. Strelow (1950)
Kansas: E. F. Miltner (1951)
Kentucky-Tennessee: Maurice L. Miller (1952)
Louisiana: S. S. Crawford (1952)
Maryland-Delaware: C. E. Keefer (1951)
Michigan: L. F. Oeming (1952)
Missouri: A. W. Wymore (1951)
Montana: K. L. Chrysler (1950)
New England: F. L. Flood (1951)
New Jersey: L. J. Fontenelli (1951)
New York: G. E. Symons (1951)
North Carolina: R. S. Phillips (1952)
Ohio: B. M. McDill (1951)
Oklahoma: Frank S. Taylor (1950)
Pacific Northwest: C. M. Howard (1950)
Pennsylvania: C. H. Young (1952)
Puerto Rico: Alberto Hernandez (1950)
Rocky Mountain: L. O. Williams (1951)
South Carolina: George A. Rhame (1952)
Switzerland: W. Dardel (1951)
Texas: J. H. Sorrells (1951)
Virginia: L. L. Hedgepeth (1950)
West Virginia: K. S. Watson (1950)
At Large: R. H. Gould (1952)
At Large: Don E. Bloodgood (1950)
At Large: Carl E. Green (1951)
W. and S. Wks. Mfgrs.: R. S. Rankin (1950)
W. and S. Wks. Mfgrs.: W. A. Hardenbergh (1951)
Ex-Officio: V. M. Ehlers
Ex-Officio: M. M. Cohn
Ex-Officio: Earnest Boyce
Ex-Officio: F. W. Gilcreas
Ex-Officio: Willem Rudolfs
Ex-Officio: W. J. Orchard
* Successor not yet designated.

SEWAGE AND INDUSTRIAL WASTES

REG. U. S. PAT. OFF.

A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

PUBLICATION OFFICE

Prince and Lemon Sts., Lancaster, Pa.

EDITORIAL AND EXECUTIVE OFFICES

325 Illinois Bldg., Champaign, Ill. Send all manuscripts, advertising copy, subscriptions, address changes, etc. to this address.

SUBSCRIPTION RATES

Members of local sewage works associations affiliated with the Federation, $5.00 per year.

Non-members: U. S. and Canada, $7.50 per year; other countries, $9.00. (Foreign subscriptions must be accompanied by International Money Order.)

Single copies: United States, $1.00 each; Foreign, $1.25 each.

CLAIMS

No claims will be allowed for copies of Journals lost in the mails unless such claims are received within sixty (60) days of the date of issue and no claims will be allowed for issues lost as a result of insufficient notice of change of address. "Missing from files" cannot be accepted as the reason for honoring a claim.

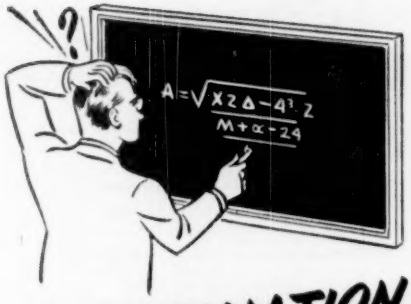
MAILING PERMIT

Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized October 4, 1945.

REFERENCE SERVICE

Sewage and Industrial Wastes is indexed regularly by *Industrial Arts Index* and *Engineering Index*.

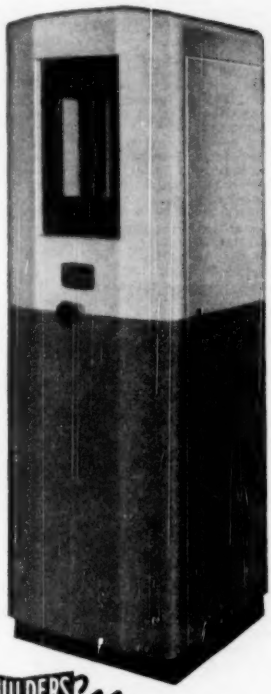
Microfilm copies of this Journal may be procured from University Microfilms, Ann Arbor, Mich. This service is limited to regular subscribers only.



CHLORINATION WITHOUT COMPLICATION

Chlorination *can* be simple, and Builders Chlorinizers will prove it to you. Here, at last, are chlorine gas feeders that give the same good service winter or summer, that require minimum attention and maintenance, and that simplify plant operation instead of complicating it. It's easy to get accurate chlorination with Builders Chlorinizers — your regular plant personnel is fully capable of operating these reliable feeders.

Simplicity means safety, too. The powerful, spring-loaded chlorine control valve delivers the exact amount of chlorine required — yet is ready to stop the flow instantly, if *any* condition occurs to interfere with *safe* operation. It will pay you to learn more about these and the many other advantages of Builders Chlorinizers: for manual, semi-automatic, program, or flow-proportional chlorination. For Bulletins and engineering information, address Builders - Providence, Inc. (Division of Builders Iron Foundry), Providence 1, R. I.



BUILDERS *Chlorinizers*

The chlorine gas feeders with extra features

BUILDERS PRODUCTS

The Venturi Meter • Propelofio and Orifice Meters • Kennison Nozzles Venturi Filter Controllers and Gauges Conveyofio Meters • Type M and Flo-Watch Instruments • Wheeler Filter Bottoms • Master Controllers • Chlorinizers — Chlorine Gas Feeders • Filter Operating Tables • Manometers Chronofio Telemeters

BUILDERS PROVIDENCE

Instruments

FSWA MEMBER ASSOCIATIONS

Alabama Water and Sewage Assn.*
ALEX O. TAYLOR, *Secretary*
Box 69
Alabama Polytechnic Institute
Auburn, Alabama

Argentina Society of Engineers, Sanitary Engineering Div.
EDMUND B. BESSELIEVRE, *FSWA Contact Member*
c/o The Dorr Company
Barry Place
Stamford, Conn.

Arizona Sewage and Water Works Assn.*
MRS. HELEN ROTTHAUS, *Sec.-Treas.*
c/o Sanitary Engineering Div.
Arizona State Dept. of Health
Capitol Building
Phoenix, Ariz.

Arkansas Water and Sewage Conf.*
DR. HARRISON HALE, *Sec.-Treas.*
118 Chemistry Bldg.
Fayetteville, Ark.

California Sewage Works Assn.
DR. LAWRENCE H. COOK, *Sec.-Treas.*
Box 696
Menlo Park, Calif.

Canadian Institute on Sewage and Sanitation
DR. A. E. BERRY, *Sec.-Treas.*
Ontario Dept. of Health
Sanitary Engineering Div.
Toronto 8, Ontario, Canada

Central States Sewage Works Assn.
PAUL W. REED, *Sec.-Treas.*
U. S. P. H. S.
c/o 69 W. Washington St.
Chicago 2, Ill.

Dakota Water and Sewage Works Conf.

North Dakota Section*
JEROME H. SVORE, *Sec.-Treas.*
c/o State Dept. of Health
Bismarck, N. Dak.

South Dakota Section*
CHARLES E. CARL, *Sec.-Treas.*
c/o Div. of Sanitary Engineering
State Board of Health
Pierre, S. Dak.

Federal Sewage Research Assn.
LEONARD B. DWORSKY, *Sec.-Treas.*
c/o Div. of Water Pollution Control
U. S. P. H. S.
Washington 25, D. C.

Florida Sewage Works Assn.
PERRY M. TEEPLE, *Sec.-Treas.*
Florida State Board of Health
P. O. Box 210
Jacksonville, Fla.

Georgia Water and Sewage Assn.*
L. E. WALLER, *Sec.-Treas.*
Rt. 12, Box 246
Atlanta, Ga.

Iowa Sewage Works Assn.
LEO HOLTKAMP, *Sec.-Treas.*
E. Ohio St.
Webster City, Iowa

Institution of Sanitary Engineers
ERNEST BALSOM, *Secretary*
118 Victoria St.
Westminster, S. W. 1
London, England

Institute of Sewage Purification
MARTIN LOVETT, *FSWA Contact Member*
206 Bradford Rd.
Wakefield, Yorks, England

Kansas Sewage Works Assn.
DWIGHT F. METZLER, *Sec.-Treas.*
c/o State Board of Health
Marvin Hall
University of Kansas
Lawrence, Kans.

Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.
R. PAUL FARRELL, *Sec.-Treas.*
420 Sixth Ave., N.
Nashville 3, Tenn.

Louisiana Conference on Water Supply and Sewerage*
DAN WINTERS, *Sec.-Treas.*
Gulf Public Service Co., Inc.
New Iberia
Louisiana

Maryland-Delaware Water and Sewerage Assn.*
W. M. BINGLEY, *Sec.-Treas.*
2411 N. Charles St.
Baltimore 18, Md.

Michigan Sewage Works Assn.
D. M. PIERCE, *Sec.-Treas.*
Michigan Dept. of Health
Room 334 Administration Bldg.
Lansing 4, Michigan

Missouri Water and Sewerage Conf.*
WARREN KRAMER, *Sec.-Treas.*
c/o State Office Bldg.
Jefferson City, Mo.

Montana Sewage Works Assn.
H. B. FOOTE, *Sec.-Treas.*
Div. of Sanitary Engineering
State Board of Health
Helena, Montana

New England Sewage Works Assn.
WALTER E. MERRILL, *Sec.-Treas.*
c/o State Dept. of Health
511-A State House
Boston, Mass.

New Jersey Sewage Works Assn.
MICHAEL S. KACHORSKY, *Sec.-Treas.*
P. O. Box 766
Manville, N. J.

New York Sewage and Industrial Wastes Assn.
RALPH C. SWEENEY, *Sec.*
c/o State Dept. of Health
615 Commerce Bldg.
Rochester 4, N. Y.

North Carolina Sewage Works Assn.
E. C. HUBBARD, *Sec.-Treas.*
North Carolina State Board of Health
Raleigh, N. C.

Ohio Sewage and Industrial Wastes Treatment Conf.
J. E. RICHARDS, *Acting Sec.-Treas.*
302 Dept. of State Bldg.
Columbus, Ohio

Oklahoma Water, Sewage and Industrial Wastes Conf.*
H. J. DARCEY, *Sec.-Treas.*
State Dept. of Health
Oklahoma City 5, Okla.

Pacific Northwest Sewage Works Assn.
W. P. HUGHES, *Sec.-Treas.*
City Engineer's Office
Lewiston, Idaho

Pennsylvania Sewage and Industrial Wastes Assn.
B. S. BUSH, *Sec.-Treas.*
c/o Pennsylvania Dept. of Health
Kirby Health Center
Wilkes-Barre, Pa.

Puerto Rico Water and Sewage Works Assn.
ALVAH R. PIERCE, *Sec.-Treas.*
c/o Puerto Rico Aqueduct and Sewer Service
Box 2832
San Juan 12, Puerto Rico

Rocky Mountain Sewage Works Assn.
CARROLL H. COBERLY, *Sec.-Treas.*
Room 329
1441 Welton St.
Denver 2, Colo.

South Carolina Water and Sewage Works Assn.*
W. T. LINTON, *Sec.-Treas.*
Wade Hampton Bldg.
Columbia, S. C.

Swiss Assn. of Water and Sewage Professionals
WALTER DARDEL, *FSWA Contact Member*
Aarberg (Berne), Switz.

Texas Water and Sewage Works Assn.
V. M. EHLERS, *Sec.-Treas.*
501 W. 33rd St.
Austin, Tex.

Virginia Industrial Wastes and Sewage Works Assn.
A. H. PAESSLER, *Sec.-Treas.*
815 E. Franklin St.
Richmond 19, Va.

West Virginia Sewage and Industrial Wastes Assn.
R. G. MCCALL, *Sec.-Treas.*
c/o 406 Tiona Ave.
Durham, N. C.

* Sewage Works Section.

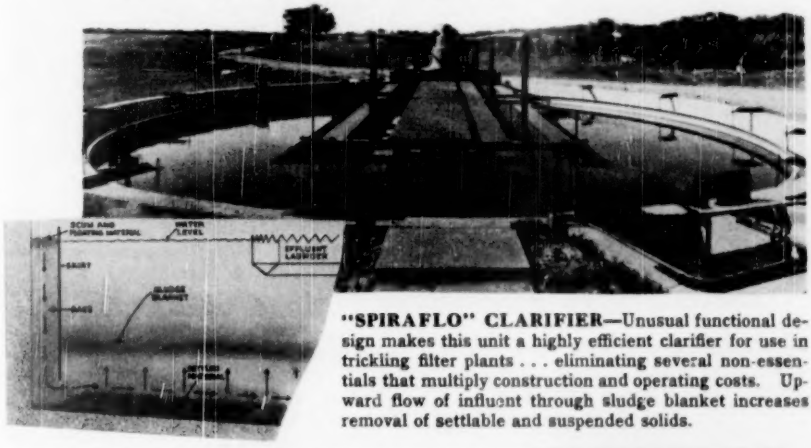
Establishing remarkable records for high purification at low cost—

YEOMANS "SPIRAFLO" CLARIFIER and "AERO-FILTER"

SINGLY . . . OR IN COMBINATION

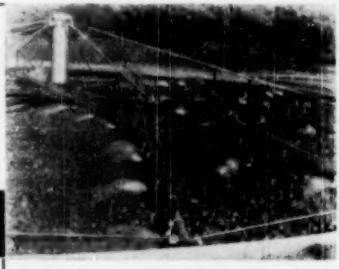
. . . especially in the treatment of strong industrial wastes

Low construction cost . . . low operating cost . . . high purifying efficiency: these are the characteristics of the Yeomans "Spiraflo" Clarifier and the "Aero-Filter System," whether used separately or in combination.



"SPIRAFLO" CLARIFIER—Unusual functional design makes this unit a highly efficient clarifier for use in trickling filter plants . . . eliminating several non-essentials that multiply construction and operating costs. Upward flow of influent through sludge blanket increases removal of settlable and suspended solids.

"AERO-FILTER" SYSTEM—Simplified design of this high capacity biological trickling filter cuts construction costs—reduces size of required filter bed by about 85%. High efficiency of single-stage operation eliminates need of installing and operating expensive conventional recirculating equipment.



YEOMANS

YEOMANS BROTHERS COMPANY
1411 N. Dayton St., Chicago 22, Ill.

Please send these bulletins:

☐ No. 6570 "Aero-Filter" ☑ ☐ No. 6790 "Spiraflo" Clarifier

Name_____

Company_____

Address_____

City_____ State_____

FIT ANY REQUIREMENTS—Overall plant efficiency is always higher when the two units are used in combination; however, plants using either type of equipment or the combination can be designed to fit any needs for treating domestic and industrial wastes.

IMPORTANT INFORMATION—Facts as to remarkable records established by Yeomans units will be helpful in your project planning. Bulletins containing performance data, field engineering data and construction cost estimates are available on request—use the coupon.

Piping for every water service From one Source . . . CRANE

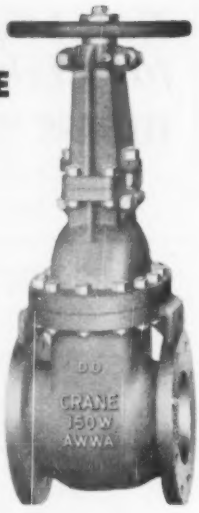
FOR TIGHT SEATING . . . EASY OPENING

Crane A.W.W.A. Iron Body Gate Valves cannot be surpassed. Crane parallel seat and double disc construction assures pressure-tight closure . . . easy opening . . . under all operating conditions. To prevent corrosion, screwed-in body seat rings are brass; discs are brass or brass faced.

Crane design assures maximum strength for all recommended services. Body and bonnet are oval shaped, with uniformly thick metal sections; tie ribs between bonnet flange and end flanges assure proper body support and guard against line strains.

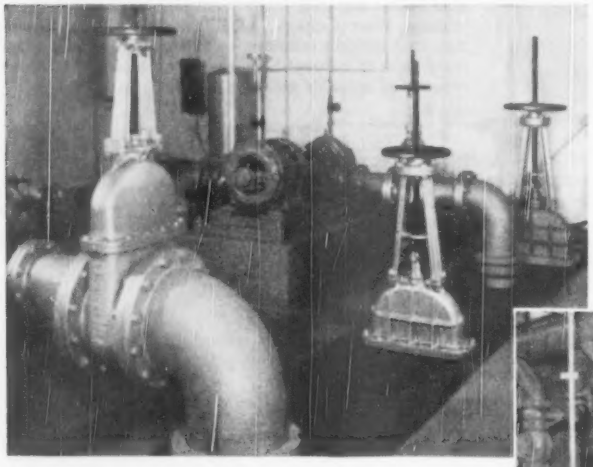
Straight-through ports give uninterrupted flow. Two-piece gland maintains uniform pressure on packing; prevents binding on stem; lengthens packing life. These valves can be motor or cylinder operated; equipped with gears and by-pass. Flanged and hub ends available. See your No. 49 Crane Catalog.

CRANE CO., 836 S. Michigan Ave., Chicago 5, Ill.
Branches and Wholesalers Serving All Industrial Areas



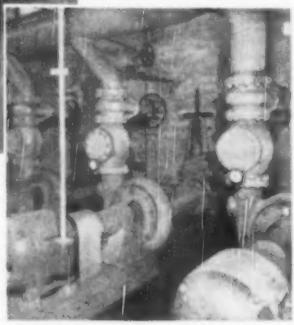
No. 2495, Outside screw and yoke. Cold Water Working Pressures: 12-inch and smaller, 200 pounds. 14-inch and larger, 150 pounds. Sizes: 2 to 24-inch.

● ***ONE ORDER TO CRANE COVERS ALL MATERIALS FOR YOUR PIPING INSTALLATIONS***



RAW WATER INLET *lines to high service pumps, featuring Crane low pressure iron body double disc gate valves.*

PUMP HOUSE *for moving industrial waste water to treating plant. Crane equipment includes shop fabricated manifold, iron body gate and check valves.*



EVERYTHING FOR EVERY PIPING SYSTEM

CRANE

VALVES • FITTINGS • PIPE • PLUMBING AND HEATING

. . . NOW REDESIGNED FOR STILL HIGHER EFFICIENCY

If you're pumping solids . . . not large enough to require regular non-clog slow speed sewage pumps . . . you'll find Economy volute mixed flow pumps the answer to your problem. Engineered for greater economy in operation, the Economy mixed flow volute line, tested and proved in twenty-two years of operation, has now been redesigned for still higher efficiency.

Built to keep pumping longer at lower cost these pumps are equipped with the highest duty bearings available, including double row, angular contact thrust bearing. Large size pumps also have a self-aligning, spherical roller radial bearing.

Capacities range from 3,000 to 50,000 G.P.M., heads from 10 to 50 ft. For complete details, write Dept. AC-4.

Centrifugal, axial and mixed flow pumps for all applications.

Economy Pumps Inc.

DIVISION OF HAMILTON-THOMAS CORP., HAMILTON, OHIO

"What d'ya mean, using all Everdur might cost less?"

JOE: *"I suppose you think you're saving money by using Everdur for only part of this job."*

JIM: *"Of course. These other materials are cheaper."*

JOE: *"But you know they won't resist corrosion as long as Everdur—you're going to have to replace them eventually."*

JIM: *"We-e-ell . . ."*

JOE: *"Then there's the fact that Everdur costs less to fabricate. It's easy to work and machine."*

JIM: *"Yeah?"*

JOE: *"Sure. And don't forget, built-up assemblies are lighter . . . easier to operate. That cuts costs."*

JIM: *"Okay, okay. You win. I guess we will be money ahead to use Everdur all around."*

Dozens of sewage plant and waterworks case histories testify to the efficiency and long-range economy of using Everdur® to resist corrosion in such installations. These ANACONDA Copper-Silicon Alloys combine the corrosion resistance of copper with high tensile strength.

Everdur is available in practically all wrought forms such as sheets, plates, rods, bars, and in structural shapes such as angles, channels, tee shapes and "I" beam sections; also in casting ingots. If you would like to know more, just write to The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

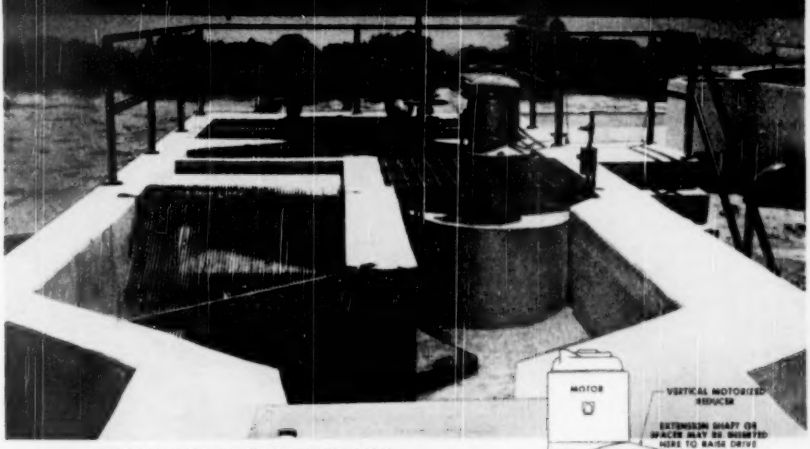
® Reg. U. S. Pat. Off. 49172

Where corrosion resistance counts —use Everdur

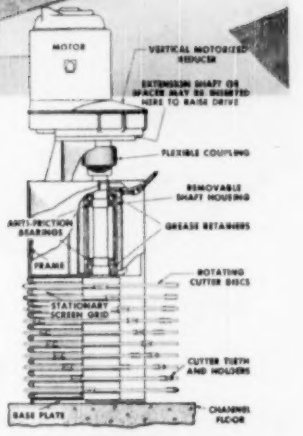
ANACONDA®
COPPER-SILICON ALLOYS

GRIDUCTOR®

STRAIGHT CHANNEL SEWAGE SCREENING AND CUTTING



GRIDUCTOR INSTALLATION (Size 36), DAYTONA BEACH, FLORIDA



Combines Coarse and Fine Screening Actions with Cutting and Shearing

HERE'S a *better* way to reduce the size of solids! GRIDUCTOR does it by intermittent cutting and shearing without excessively increasing the dissolved organic content of the sewage. Easily and quickly installed in new or existing sewage screen channels. Protects treatment plant units from fouling and clogging. Delivers more readily settleable solids to primary clarifier, and larger quantity of sludge to digester increasing gas production. Get all the facts about this sturdy, efficient equipment. Send for Bulletin No. 5100. Write today . . or, ask our nearest field engineer for complete information.

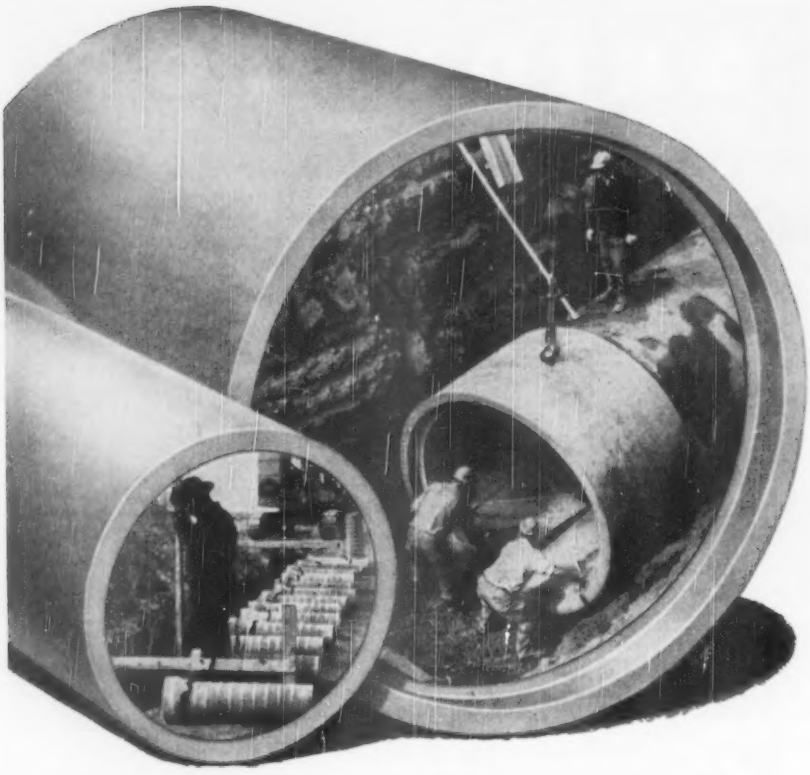
INFILCO

• BETTER WATER CONDITIONING AND WASTE TREATMENT SINCE 1894 •

INFILCO INC.

SALES OFFICES IN TWENTY SIX PRINCIPAL CITIES

WORLD'S LEADING MANUFACTURERS OF WATER CONDITIONING AND WASTE TREATING EQUIPMENT



Large or small . . . you can solve your sewer problems

with *CONCRETE PIPE*

WHETHER your immediate sewer need is a large diameter storm sewer or a smaller sanitary sewer for domestic wastes concrete pipe is the ideal answer. Here are the reasons why;

- Its uniformly dense structure and joints that can be made watertight assure minimum infiltration and leakage.
- Its smooth interior finish resists the wearing action of abrasive matter and provides maximum hydraulic capacity.
- Its great strength resists severe impact and sustains heavy overburdens.
- Its unusual durability enables it to give many long years of heavy-duty service. Many concrete sewers have given a century of unexcelled service.

Concrete pipe is economical, too, because its first cost is moderate, its life is long and its maintenance low. These three factors result in *low-annual-cost* sewer service—the true measure of pipe line economy.

PORTLAND CEMENT ASSOCIATION

33 W. Grand Avenue
Chicago 10, Illinois

A national organization to improve and extend the uses of portland cement and concrete...through scientific research and engineering field work

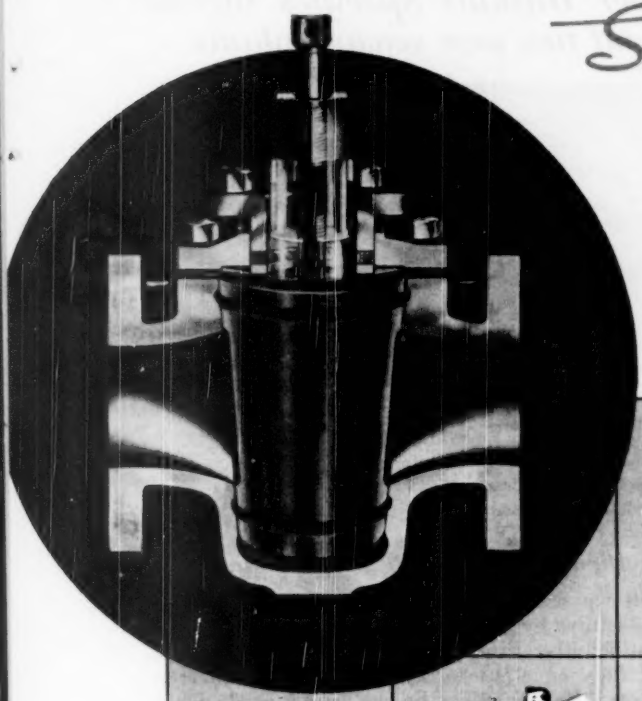
IN NO OTHER VALVE

So many features

and every one

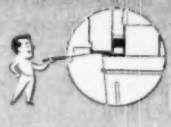
IMPORTANT!

FOR SEWAGE DISPOSAL SERVICE



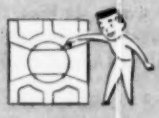
A TIGHT SHUT-OFF ALWAYS
Sealed with lubricant

RESIST CORROSION, EROSION
Lubricant protects parts



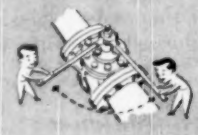
RESILIENT SHOULDER SEAL
Allows jacking of plug

RELUBRICATE UNDER PRESSURE
No need to shut down line



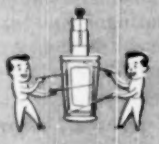
UNEXPOSED VALVE SEAT
No contact with line fluid

ADJUSTABLE UNDER PRESSURE
Simple external adjustment



QUARTER TURN
Simple sliding action

MOST COMPACT SIZES
For restricted areas



PRESSURE-SEALED PORTS
"Inside-port" lubrication

SAVE MAN-HOURS
Use Hypermatic lubricant

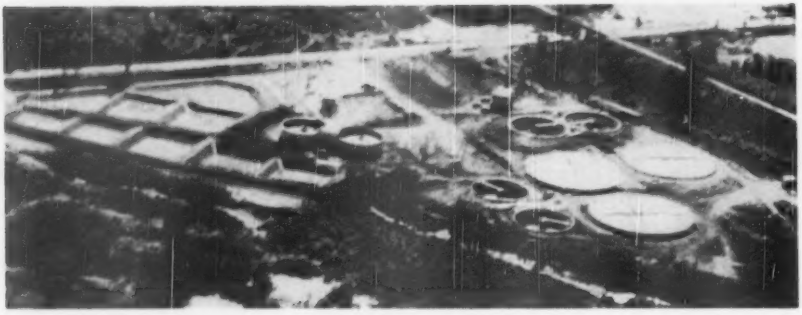
ROCKWELL

Nordstrom VALVES

***Nordstrom Valve Division*—ROCKWELL MANUFACTURING CO.**
400 North Lexington Avenue, Pittsburgh 8, Pa., Offices in all principal cities

Export — Rockwell Mfg. Co., International Division, Empire State Building, New York 1

Consulting Engineer Haskins Specifies Inertol Paints throughout two new sewage plants



North Side Sewage Plant, the larger of the two plants at Joplin, Missouri.
Inertol colors and black bituminous paints applied throughout both plants.
Consulting Engineer: Charles H. Haskins, Kansas City.
Contractor for North Side Plant: Eby Construction Company, Wichita.
Contractor for South Side Plant: Lippert Brothers, Oklahoma City.

Stringent paint specifications for both Joplin plants

Exterior steel and equipment exposed to fumes: "Rustinhibitive Primer and Ramuc Utility Enamel as manufactured by Inertol Co., Inc. or approved equal." Exposed interior piping: "Rustinhibitive Primer and . . . a tough high-gloss protective enamel similar and fully equal to Inertol Glamortex." Concrete ceilings, upper walls, dadoes, floors: "Ramuc Utility Enamel or approved equal." Concrete and steel submerged in sewage: "approved acid-resistant paint similar and fully equal to Inertol Standard and Inertol Standard Thick respectively."

For exposed surfaces, the engineer chose the colors Battleship Grey, Dark Green, White and Medium Grey. For submerged surfaces, Black.

Why specify Inertol coatings?

Specify Inertol to satisfy clients and eliminate complaints on the paint job. Since Inertol chemists employ tough, chemical-resistant resins and pigments, the finished coatings stand up to abrasion, fumes, condensation and submersion. No peeling, no blistering, no fading. Inertol paints enduringly beautify and protect sewage plants.

Local Inertol representatives for your convenience

Drop a post card to Inertol: "Have your local man see me about painting specifications."

INERTOL CO., INC.

19 South Park
San Francisco 7, California

480 Frelinghuysen Avenue
Newark 5, New Jersey

Inertol, Ramuc, Glamortex—Trademarks registered U. S. Pat. Off.

GENERAL CHEMICAL "ALUM"

...Equally Efficient for Coagulation of WATER and SEWAGE!

FOR WATER WORKS

1. Produces crystal clear water.
2. Gives better floc formation.
3. Promotes better settling and longer filter runs.
4. Aids in reduction of tastes and odors.
5. Has no chlorine demand.
6. Is a *low cost* coagulant.
7. Superior in tests against other coagulants.
8. High in quality. Its constant uniformity can be depended upon.

Aluminum Sulfate is almost universally accepted by water experts as the best coagulant for removal of turbidity, color and bacteria from water . . . and General Chemical Aluminum Sulfate is the outstanding choice the nation over. That's because its high quality and constant uniformity have given it a time-tested reputation for reliability among operating men in towns and cities all over America.

Municipal officials in charge of sewage treatment also find that clarity of sewage effluent is easily obtainable with General Chemical Aluminum Sulfate for the many reasons outlined above. For your water and sewage disposal systems, specify General Chemical "Alum"—*preferred by most American cities.*

FOR SEWAGE PLANTS

1. Clean, easy to handle.
2. Dry feeds well or dissolves readily for solution feeding.
3. Simple application. Requires only low cost feeding apparatus and minimum attention.
4. Clear, colorless effluents are possible.
5. Sludge digests readily.
6. Treated digested sludge dries quickly with minimum of odor.
7. Chlorine consumption is cut due to lower demand of clarified sewage.
8. Economical to use.

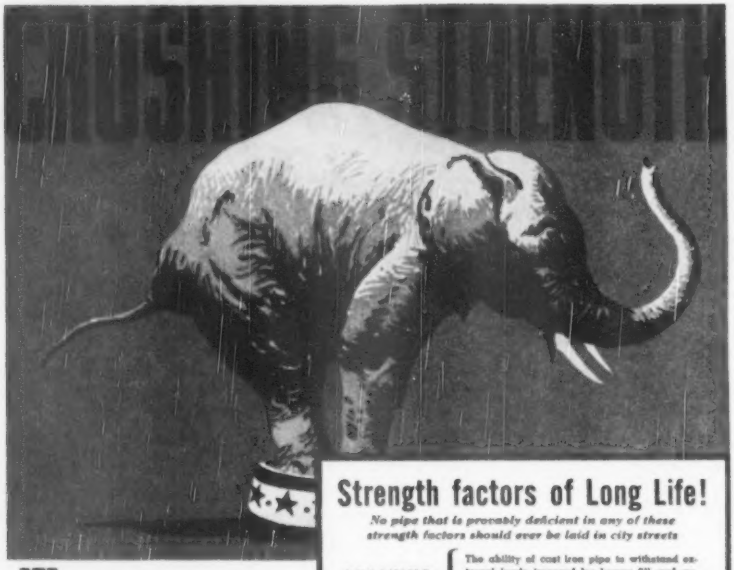
GENERAL CHEMICAL DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

Offices: Albany • Atlanta • Baltimore • Birmingham • Boston Bridgeport • Buffalo • Charlotte • Chicago • Cleveland • Denver Detroit • Houston • Kansas City • Los Angeles • Minneapolis New York • Philadelphia • Pittsburgh • Portland (Ore.) Providence • San Francisco • Seattle • St. Louis • Wenatchee Yakima (Wash.)

In Wisconsin: General Chemical Company, Inc., Milwaukee, Wis.

In Canada: The Nichols Chemical Company, Limited
Montreal • Toronto • Vancouver

BASIC CHEMICALS
FOR AMERICAN INDUSTRY ©



Without crushing strength—or, for that matter—without all of the strength factors listed opposite—no pipe laid 100 years ago in *city streets* would be in service today. But, in spite of the evolution of traffic from horse-drawn vehicles to heavy trucks and buses—and today's vast complexity of subway and underground utility services—cast iron gas and water mains, laid over a century ago, are serving in the streets of more than 30 cities in the United States and Canada. Such service records prove that cast iron pipe combines all the strength factors of long life with ample margins of safety. No pipe that is provably deficient in any of these strength factors should ever be laid in city streets. Cast Iron Pipe Research Association, Thos. F. Wolfe, Engineer, 122 So. Michigan Ave., Chicago 3.

Strength factors of Long Life!

No pipe that is provably deficient in any of these strength factors should ever be laid in city streets

CRUSHING STRENGTH — The ability of cast iron pipe to withstand external loads imposed by heavy fill and unusual traffic loads is proved by the Ring Compression Test. Standard 6-inch cast iron pipe withstands a crushing weight of more than 14,000 lbs. per foot.

BEAM STRENGTH — When cast iron pipe is subjected to beam stress caused by soil settlement, or disturbance of soil by other utilities, or resting on an obstruction, tests prove that standard 6-inch cast iron pipe in 10-foot span sustains a load of 15,000 lbs.

SHOCK STRENGTH — The toughness of cast iron pipe which enables it to withstand impact and traffic shocks, as well as the hazards in handling, is demonstrated by the Impact Test. While under hydrostatic pressure and the heavy blows from a 50 pound hammer, standard 6-inch cast iron pipe does not crack until the hammer is dropped 8 times on the same spot from progressively increased heights of 6 inches.

BURSTING STRENGTH — In full length bursting tests standard 6-inch cast iron pipe withstands more than 2500 lbs. per square inch internal hydrostatic pressure, which proves ample ability to resist water-hammer or unusual working pressures.

CAST IRON PIPE SERVES FOR CENTURIES

SEWAGE AND INDUSTRIAL WASTES

The Journal of the Federation of Sewage Works Associations

Volume 22 | APRIL, 1950 | Number 4

Contents

Sewage Works

Tests and Studies on Air Diffusers for Activated Sludge. By Norval E. Anderson 461
Discussion by John J. Wirts 475

Sewage Works Development in the Massachusetts Metropolitan District. By Karl R. Kennison 477

The Oxygen Requirements of Activated Sludge Determined by Manometric Methods. II. Chemical Factors Affecting Oxygen Uptake. By P. S. S. Dawson and S. H. Jenkins 490

Study of the Nitrification Phase of the B.O.D. Test. By A. M. Buswell, Irene Van Meter, and J. R. Gerke 508

Industrial Wastes

Minimum Requirements for the Control of Industrial Wastes. Washington Pollution Control Commission 514

The Characteristics of Wastes from Chicken Packing Plants. By H. Heukelekian, H. E. Orford, and J. E. Cherry 521

Wastes from Poultry Dressing Establishments. By Ralph Porges 531

High-Rate Trickling Filter Operation on Formaldehyde Wastes. By B. W. Dickerson 536
Discussion by H. Heukelekian 546

Industrial Wastes Disposal at Pittsburgh. By John F. Laboon 549
Discussion by Hayse H. Black 553

The Operator's Corner

Pass That Experience On 555

Gas Engine Experience at Butler, Pa. By T. R. Haseltine 556

What Operators Want in Sewage Plants 561

The Daily Log—Aurora, Ill. By Walter A. Sperry 564

Experiments in Composting Digested Sludge at Austin, Texas. By A. H. Ullrich and M. W. Smith 567

Tips and Quips 570

Member Association Meetings 573

Reviews and Abstracts 574

Book Review 591

Professional Opportunity 592

W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois
Herbert P. Orland, *Assistant Editor* Dr. F. W. Mohlman, *Advisory Editor*
Kathleen E. Fox, *Editorial Assistant*

Copyright, 1950, by the Federation of Sewage Works Associations, Inc. Reprints from this publication may be made only if permission of the Editor is secured and on condition that the full title of the article, name of the author and complete reference are given. The Federation assumes no responsibility for opinions or statements of facts expressed in papers or discussions published in this *Journal*.

CHECK THESE FACTS...

ON DORR CLARIFIER MAINTENANCE COSTS!

REPAIR COSTS ON DORR TYPE S (ROUND) CLARIFIERS

SIZE	PURCHASE PERIOD	YEARS IN SERVICE	NUMBER OF UNITS	REPAIR COSTS		REPAIR COST AS % OF ORIGINAL COST
				TOTAL	PER UNIT	
100'-200' Dia.	1931-42	4-15	115	$3,568	$31	0.27
Under 100' Dia.	1932-33	13-14	30	812	27	1.00
Under 100' Dia.	1934-35	11-12	65	2,121	33	0.71

A glance at the figures above will tell you exactly what repair costs can be expected with Dorr Clarifiers.

These figures are substantiated facts . . . not estimates, guesswork or wishful thinking. We believe they cannot be matched.

Repair costs are one of the primary factors upon which Clarifier excellence should be judged. Are you getting the best?

Sixteen Dorr Sifeed Clarifiers at Easterly Treatment Plant, Cleveland, Ohio, installed in 1932.

We'd like to tell you how Dorr Clarifiers stack up on performance, too. Ask a Dorr engineer for the facts.

DORRCO

THE DORR COMPANY, ENGINEERS
BARRY PLACE, STAMFORD, CONN.
NEW YORK • ATLANTA • TORONTO
CHICAGO • DENVER • LOS ANGELES
RESEARCH AND TESTING LABORATORIES
WESTPORT, CONN.
SUGAR PROCESSING
PETREE & DORR DIVISION, STAMFORD, CONN.
ASSOCIATES AND REPRESENTATIVES
Dorr Technical Services and Equipment Are Also Available Through Associated Companies and Representatives in the Principal Cities of the World. Names and Addresses on Request.

RESEARCH ENGINEERING DORR EQUIPMENT

Sewage Works

TESTS AND STUDIES ON AIR DIFFUSERS FOR ACTIVATED SLUDGE *

By Norval E. Anderson

Engineer of Treatment Plant Design, The Sanitary District of Chicago, Ill.

Introduction

Designers and operators of sewage works learn most from the difficulties encountered. The Sanitary District of Chicago was led into an intensive study of air diffusers because of clogging difficulties at its Southwest sewage treatment works, in contrast to some 20 years of trouble-free operation at its North Side works.

These tests were started on a small scale in 1941, after the plant had been in operation for about two years. In 1942, small groups of porous plates and tubes of various permeability were installed, mostly in one tank, with connections for pressure loss readings to determine relative clogging rates.

The concept of diffuser test requirements continued to expand until, by the end of 1945, each of the 8 aeration tanks of battery A was completely fitted with a different diffuser system; and the 8 tanks operated in a parallel test for determining both the relative clogging rate and relative air economy of the respective systems. Each of these tanks is 136 ft. by 434 ft., arranged in four passes, making the flow channels 34 ft. wide center to center of walls and 1,736 ft. long, with a water depth of 15 ft. over diffuser plates; each has a nominal treating capacity of 32 m.g.d.

* Presented at 22nd Annual Meeting, Federation of Sewage Works Assns.; Boston, Mass.; Oct. 17–20, 1949.

Comparative Tests

The characteristics of the different diffuser systems which made up the comparative tests are summarized in Table I. The comparative test units were operated under regular plant conditions, with the normal fluctuations of sewage flow and strength in the entire battery of test tanks, but with equal flow of mixed liquor to each test tank. The distribution was checked by Venturi meter readings on the effluent of each aeration tank at 2-hr. intervals. The sludge from all 24 final settling tanks of the battery is returned to a common channel, where it is mixed with the sewage from the preliminary settling tanks, making the mixed liquor influent to each test tank the same.

Yearly averages of the general operating data for the major test period are given in Table II.

Special records of test data were kept in addition to the normal operating records.

Test Data for Relative Air Economy

For determining the relative air economy of the different test tanks, the air supply was adjusted to produce as closely as possible the same dissolved oxygen at the effluent end of each tank. Also, the air supply to groups of diffusers was regulated to give uniform distribution throughout the

length of each tank. For a time, D.O. determinations were also made at the quarter points of tanks as a check on the effluent comparisons. As a further check, simultaneous oxygen utilization determinations were made throughout the lengths of two tanks at one time.

Each aeration tank is supplied by two air mains, one to the influent half and one to the effluent half. Venturi meter readings and necessary valve adjustments were made on each air main every 2 hr. Dissolved oxygen determinations were made by the Winkler method every 4 hr. on each tank. The readings were averaged for each day and the daily averages were averaged for each month. The monthly averages of air used and the resulting dissolved oxygen at the effluent end of each tank are given in Table III.

Test Data for Relative Clogging Rate

In order to determine the relative clogging rate of the different air diffusers, frequent pressure readings were coordinated with the number of days of service, the cumulative total amount of air passed per diffuser, the amount of dirt in the air supply, and a log of events that could affect pressure losses.

Pressure readings were taken at about weekly intervals by mercury manometers on each of the two air mains to each test tank. The piping losses were computed for the range of air rates for each tank and checked by occasional readings. The net loss through diffusers in each case was obtained by deducting the static head and piping loss from the air main pressure readings. However, the reported losses

TABLE I.—Characteristics of Diffuser Systems Tested

Tank No.	Period of Test		Diffuser Type, Permeability, and Make	Number of Diffusers			Diffuser Arrangement	Diffusion Band, Feet	
	From	To		Infl. Half	Effl. Half	Total		Width	Center to Wall
A-1	6-18-45	6-6-47	Plates 80 Norton	1,776	705	2,481	4 rows in first bay, 1 row in last 3 bays	9.3 1.0	6.4 2.3
	8-11-47	—	Plates 80 Norton	2,124	1,410	3,534	4 rows in first bay, 2 rows in last 3 bays, Same plates in 1st bay	9.3 2.7	6.4 3.1
A-2	5-22-45	—	Plates 40 Carborundum	1,360	1,360	2,720	Plates clamped in 4-plate cast-iron holders placed normal to wall[1]	4.3	3.9
A-3	12-20-45	10-28-46	Porous tubes[2]	1,488	1,076	2,564	Swing diffusers, retractable headers: tubes submerged 13.5 ft.[1]	4.7	3.5
	10-29-46	6-16-47	Porous tubes	1,338	1,076	2,414			
	6-17-47	10-13-47	Porous tubes	1,106	1,076	2,182			
	10-14-47	12- 3-48	Porous tubes	1,006	1,000	2,006			
	3- 4-49	—	Precision tubes	1,002	998	2,000			
A-4	5-24-45	—	Plates 80	1,410	1,410	2,820	2 rows	2.7	3.1
A-5	8-15-45	12-15-48	¾ × 10¼-in. brass pipe[3] 24 slots 0.04 in. by pipe dia.	729	729	1,458	Screwed into 4-in. pipe headers, submerged 15.0 ft.	1.7	3.3
	1- 1-49	—	Porous tubes[4]	1,122	1,116	2,238	Connected to 4-in. header with pipe fittings, submerged 15.0 ft.	3.5	4.0
A-6	8-10-45	—	Plates 80 Norton	2,820	2,820	5,640	4 rows Bays 1 and 3 Bays 2 and 4	9.3 6.0	6.4 4.8
A-7	5-17-45	3-19-46	Plates 40 Carborundum	1,360	1,360	2,720	Plates clamped on both sides of vertical cast-iron holders submerged 13.0 ft. to plate center line	0.5	3.3
	5-17-46	—	Plates 80 Norton						
A-8	5-21-45	8-26-46	Plates 80 Norton	705	705	1,410	One row	1.0	2.3
	9-17-46	—	Plates 120 Norton						

[1] Air to influent half of tank given secondary filtering by "Staynew" pipeline type filters using a woolen fabric ("Feltex") medium.

[2] Original tubes: Influent: 712 Norton 40-perm., 78 Norton 80-perm., 78 Carborundum 65-perm., and 620 carbon "Teardrop" 26-permeability. Effluent: 1,076 Carborundum 65-perm.

[3] From July 9, 1946, to May 15, 1947, brass tubes of same dimensions except slots 0.04 × 0.50 in. were used.

[4] Tubes were removed from tank A-3 and acid cleaned before installation in tank A-5.

TABLE II.—General Operating Data During Test Period

Item	Year			
	1945[1]	1946	1947	1948
Sewage flow, battery A (m.g.d.)	133	157	148	266
Return sludge, battery A (m.g.d.)	64	72	67	96
Approx. total flow per tank (m.g.d.)	33	29	29	46
5-day B.O.D. (p.p.m.):				
Raw sewage	162	171	158[2]	175[3]
Preliminary effluent	120	129	—	—
Final effluent, battery A	13	11	11	8
Suspended solids (p.p.m.):				
Raw sewage	208	226	205[2]	225[3]
Preliminary effluent	133	156	—	—
Final effluent, battery A	13	14	14	16
Susp. sol., aer. mixture (p.p.m.)	1,800	1,895	1,967	2,030
Aeration period (hr.)[4]	4.7	5.2	5.1	3.4

[1] June–December, 1945.
[2] Based partly on estimates.
[3] Based on estimates.
[4] Based on mixed liquor flow.

Starting on February 2, 1948, West Side Imhoff tank effluent was treated in battery A. Treatment in battery B started February 11, 1948. For the entire year 1948 the sewage flow in battery A averaged 46 per cent West Side effluent, which averaged 83 p.p.m. 5-day B.O.D. and 91 p.p.m. suspended solids. No analyses of Southwest raw sewage or preliminary effluent were available in 1948.

do include losses due to valve throttling as noted. A graphical summary of the net pressure loss determinations is given in Figure 1.

Analysis of Data for Relative Air Economy

Comparison of the respective amounts of air required to produce the same dissolved oxygen at the effluents of the aeration tanks was employed to indicate relative air economy because of the relation between dissolved oxygen, rate of oxygen absorption, and rate of utilization which would obtain under the conditions of the test.

It has been established (1) that "When a liquid and a moderately soluble gas come into contact and the liquid is kept thoroughly mixed so that it may be regarded as of uniform composition at all points, the rate of solution of the gas varies directly as the degree of undersaturation of the liquid." The rate at which oxygen is absorbed must correspond closely to the rate at which it is utilized by the sludge, as the dissolved oxygen present at any time is a very small part of the total oxygen taken into solution during the aeration period. Therefore, under the test conditions, the same D.O. in the effluent would indicate equal oxygen utilization in the test tanks; and the quantity of air required to produce this D.O. in each tank would indicate the relative air economy, or efficiency, of the respective diffuser systems.

The test conditions were:

1. Equal quantities of identical mixed liquor influent.
2. Uniform distribution of air throughout the length of each tank to insure uniform mixing.
3. The quantity of air to each tank adjusted to give the same D.O. at the effluents.

TABLE III.—Dissolved Oxygen, Effluent End of Aeration Tanks

Year	Month	Tank A-1 Plates: 80 Perm. 4 Rows 1st Bay 1 Row Other Bays		Tank A-2 Plates: 40 Perm. C.I. Containers Normal to Wall		Tank A-3 Tubes, Various Perm., on Swing Headers		Tank A-4 Plates: 80 Perm. 2 Rows in All Bays		Tank A-5 Slotted Brass Tubes		Tank A-6 Plates: 80 Perm. 4 Rows in All Bays		Tank A-7 Plates: 40–80 Perm.[1] Vertical Plate Containers		Tank A-8 Plates: 80 Perm. 1 Row in All Bays	
		1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)
1945	June	—	—	12.6	3.0	—	—	12.5	3.1	—	—	—	—	13.2	2.7	12.8	3.2
	July	11.2	3.2	11.9	3.1	—	—	12.1	3.1	—	—	—	—	16.2	3.2	12.4	3.2
	Aug.	12.4	3.6	11.3	3.8	—	—	11.9	3.8	—	—	10.7[2]	4.1[2]	15.5	3.8	12.3	3.6
	Sept.	11.8	3.8	10.0	4.0	—	—	11.4	3.6	13.7	3.6	11.0	4.1	15.6	4.1	11.9	3.6
	Oct.	12.8	3.4	11.4	3.7	—	—	10.9[3]	3.7[3]	16.3	3.3	11.6	3.9	16.2	3.7	13.4	3.5
	Nov.[4]	11.0	3.8	10.6	4.2	—	—	—	—	15.1	3.7	10.0	3.9	15.0	3.9	11.1	4.0
	Dec.[4]	5.5	3.5	5.2	4.1	—	—	5.2	3.5	7.7	3.9	5.1	3.5	8.0	3.4	5.1	3.4
1946	Jan.	6.4	4.1	6.6	4.1	6.4	4.5	5.7	4.9	10.6	3.9	5.5	3.9	8.8	3.1	6.4	3.7
	Feb.	7.1	3.3	7.4	2.7	6.8	3.5	6.9	5.0	12.9	2.7	7.1	3.9	9.4	3.3	7.2	3.3
	Mar.	11.6	5.4	9.9	4.1	11.6	5.6	10.8	6.5	13.1	5.3	11.2	5.9	6.2[4]	3.3[4]	11.2	5.4
	Apr.	11.8	3.9	8.9[5]	3.9[5]	11.6	4.0	10.7	4.8	14.8	4.0	11.5	4.2	—	—	11.6	3.9
	May	10.9	3.4	10.1	4.5	11.0	3.6	10.0	4.6	14.3	4.2	10.4	3.9	—	—	10.4	3.6
	June	12.2	3.6	11.7	5.0	12.6	3.8	12.0	5.1	16.0[6]	5.0[6]	12.2	5.2	20.1	5.3	12.5	4.4
	July	11.2	3.8	9.8	4.3	11.3	3.8	10.4	3.9	14.6[6]	3.7[6]	9.4	3.9	14.0	3.8	11.9	4.0
	Aug.	10.4	2.8	11.3	3.5	11.6	3.0	11.6	3.3	13.9	2.9	10.9	3.4	16.0	3.4	10.6[9]	3.2[9]
	Sept.	11.2[9]	2.7[9]	11.3	4.2	11.2	3.4	11.9	3.9	13.0	3.0	10.9	4.1	17.2	4.0	11.8[10]	4.2[10]
	Oct.	11.8[11]	3.1[11]	12.8	4.0	11.4	3.5	12.0	3.9	14.8	3.0	8.6	3.5	16.8	3.7	11.3	3.7
	Nov.	8.6	2.8	10.5	3.9	10.6	4.2	11.5	4.3	12.9	3.0	11.1	4.8	18.0	4.5	8.4	3.9
	Dec.	8.9	3.5	10.8	3.9	10.3	4.4	10.8	4.9	12.8	3.4	10.2	5.2	16.4	5.0	8.0	4.4
1947	Jan.	7.3	2.6	9.4	3.4	9.4	4.2	10.4	5.3	10.8	2.9	9.8	5.4	16.0	5.3	6.3	3.6
	Feb.	8.0[12]	2.9[13]	9.2[12]	3.0[13]	9.8[13]	4.5[13]	10.6	5.0	11.9	3.2	10.8	5.7	16.4[12]	5.5[13]	7.4[12]	4.3[13]
	Mar.	9.5[13]	4.4[12]	9.3[13]	3.2[12]	11.4[12]	4.8[13]	13.2	6.1	11.7	3.4	12.8	6.6	15.8[12]	5.2[12]	8.5[13]	6.1[12]
	Apr.	6.8	5.2	—	—	8.3	6.0	9.8	7.4	9.3	5.2	9.8	7.9	13.0	6.5	—	—
	May	7.5	2.5	—	—	8.8	3.9	10.6	5.0	7.5[15]	2.8[13]	10.6	5.3	10.6	3.2	6.4	3.6
	June	—	—	12.1[14]	3.9[14]	11.7	3.0	12.6	4.6	12.1[15]	2.1[15]	13.0	5.2	13.0	2.6	8.7[16]	2.8[14]
	July	—	—	11.9	2.8	12.6	3.1	12.6	3.6	11.9	1.7	12.6	4.0	12.4	1.6	9.8	2.2
	Aug.	—	—	11.9	2.8	11.9	2.4	11.0[17]	3.1[17]	12.1	2.0	13.0	3.9	13.0	1.9	7.3[18]	2.1[18]
	Sept.	—	—	8.9	3.0	9.0	2.6	—	—	7.7[19]	2.1[19]	9.8	4.4	9.2[19]	3.3[19]	—	—
	Oct.	—	—	9.4	2.9	9.1[20]	2.5[20]	—	—	—	—	9.2	3.9	—	—	—	—
	Nov.	—	—	12.3	4.5	12.9	3.6	—	—	12.8[13]	2.6[11]	12.5	5.6	13.4[21]	3.7[21]	—	—
	Dec.	—	—	11.8	4.9	12.4	3.7	—	—	13.0	3.2	12.5	5.9	13.4	4.0		
								Averages									
Over-all	—	9.9	3.5	10.4	3.8	10.1	3.7	10.7	4.4	12.5	3.3	10.5	4.7	12.4[22]	3.5[22]	10.0	3.6
1946	All	10.2	3.5	10.1	4.0	10.5	3.9	10.4	4.3	13.6	3.7	9.9	4.3	—	—	10.1	4.0
1945	[23]	11.8	3.5	11.5	3.5	—	—	12.0	3.4	13.7	3.6	10.8	4.1	15.1[24]	3.4[24]	12.4	3.4
1946	[23]	11.2	3.2	11.0	4.2	11.6	3.5	11.5	4.0	14.4	3.6	10.8	4.2	16.8[25]	4.1[25]	11.7	4.0
1947	[23]	—	—	11.2	3.1	11.3	2.8	9.1	3.8	11.0	2.0	12.1	4.4	11.9[25]	2.3[25]	8.6	2.4
1945	[26]	7.6	4.1	7.3	3.8	8.3	4.5	7.2	5.0	11.1	4.0	7.2	4.3	8.1[26]	3.3[26]	7.5	4.0
1946	[26]	8.1	3.0	10.1	3.6	9.8	4.3	11.2	5.3	11.8	3.2	10.9	5.7	16.2[26]	5.2[26]	7.2	4.0

[1] 40 perm. June 1945 through March 1946; 80 perm. June 1946 through Dec. 1947. [2] 10th–31st. [3] 1st–11th. [4] 1st–22nd. [5] 15th–31st. [6] 1st–19th. [7] 1st–3rd and 20th–30th; new plates in effluent half starting Apr. 20, 1946. [8] 1st—23rd. [9] 1st–26th. [10] 16th–30th. [11] 5th–30th. [12] Influent gates throttled varying amounts; values not used in averages. [13] 1st–14th. [14] 6th–30th. [15] 7th–30th. [16] 1st–5th and 14th–30th. [17] 1st–27th. [18] 1st–25th. [19] 1st–15th. [20] 1st–12th and 25th–31st. [21] 10th–30th. [22] 40 perm.; 14.5 and 3.9 for 80 perm. [23] June, July, August, and September. [24] 40 perm. [25] 80 perm. [26] December, January, February, and March.

TABLE III (Continued)

Year	Month	Tank A-1 Plates: 80 Perm. 4 Rows 1st Bay 2 Rows Other Bays		Tank A-2 Plates: 40 Perm. C.I. Containers Normal to Wall		Tank A-3 Tubes, Various Perm., on Swing Headers		Tank A-4 Plates: 80 Perm. 2 Rows in All Bays		Tank A-5 Slotted Brass Tubes		Tank A-6 Plates: 80 Perm. 4 Rows in All Bays		Tank A-7 Plates: 80 Perm. Vertical Plate Containers		Tank A-8 Plates: 120 Perm. One Row in All Bays	
		1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)	1,000 C.F.M.	D.O. (p.p.m.)
1947	Aug.	10.5[27]	2.5[27]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Sept.	8.7[28]	2.7[28]	—	—	—	—	9.4[29]	2.4[29]	—	—	—	—	—	—	7.4[30]	1.8[30]
	Oct.	9.4[31]	3.0[31]	—	—	—	—	10.2	2.4	—	—	—	—	—	—	11.2	2.9
	Nov.	12.7	4.5	—	—	—	—	12.9	3.7	—	—	—	—	—	—	12.9	3.3
	Dec.	12.7	5.0	—	—	—	—	12.4	4.4	—	—	—	—	—	—	11.7	4.0
1948	Jan.	11.6	5.8	10.0	5.4	11.2	4.4	11.4	5.2	12.2	3.9	11.0	6.7	13.2	5.0	12.8	4.9
	Feb.	13.1	5.6	11.4	5.1	12.3	4.7	13.3	5.3	14.3	4.6	12.9	6.6	13.9	5.2	14.7	5.2
	Mar.	12.5	6.6	11.0	6.4	10.6	4.8	13.0	6.5	12.7	4.8	12.5	7.6	12.4	5.4	13.2	6.1
	Apr.	14.1	5.1	12.7	4.6	11.4	3.3	13.6	4.3	13.6	3.1	13.7	6.1	12.5	3.6	13.9	3.8
	May	14.1	5.2	11.0	4.5	11.2	3.4	14.0	4.5	14.1	3.2	13.5	5.9	13.8	4.2	13.9	4.3
	June	14.4	5.2	9.8	4.0	9.6	2.4	13.8	3.8	12.8	2.5	13.8	5.7	11.5	3.2	14.1	3.9
	July	14.2	4.7	9.4	3.2	9.6	2.3	13.1	3.1	12.4	2.4	12.6	5.1	10.1	2.8	13.6	3.8
	Aug.	14.2	5.0	11.1	4.3	11.3	3.9	13.5	3.9	13.4	3.3	13.8	5.9	12.2	4.1	14.2	4.4
	Sept.	14.6	5.1	10.2	3.7	11.2	3.1	14.3	3.7	13.0	2.4	13.8	5.6	13.0	2.8	14.3	3.8
	Oct.	14.8	4.2	11.5	3.2	12.9	2.8	14.9	3.1	13.8	2.1	14.6	5.6	13.8	2.6	14.9	3.2
	Nov.	15.0	5.0	11.3	3.8	12.1	3.3	15.0	4.1	13.8	2.4	15.0	6.0	13.8	3.4	15.0	3.7
	Dec.	14.8	5.0	11.3	3.3	—[32]	—[32]	14.9	4.2	14.0[33]	2.4[33]	14.8	6.0	14.3	3.4	14.9	3.9
1948	Av.	14.0	5.2	10.9	4.3	11.2	3.5	13.7	4.3	13.3	3.1	13.5	6.1	12.9	3.8	14.1	4.2
1947–48	Av.	13.8[32]	5.1[32]	—	—	—	—	13.3[34]	4.1[34]	—	—	—	—	—	—	13.3[35]	3.9[35]
						"Precision" Tubes				Ceramic and Carbon Tubes							
1949	Jan.	14.8	5.0	9.0[38]	2.4[38]	—	—	15.0	4.4	14.1[37]	5.2[37]	14.6	6.2	13.6	3.2	14.7	4.0
	Feb.	13.4	4.4	6.8[36]	2.2[38]	—	—	13.2	4.1	13.1	4.4	12.8	5.5	12.3[38]	2.7[38]	13.6	3.7
	Mar.	14.1	4.4	—	—	14.0[39]	4.1[39]	14.0	4.4	13.3	3.8	12.4	5.4	13.9	2.8	13.7	3.3
	Apr.	13.6	4.4	12.4[40]	4.1[40]	13.6	4.3	13.4	4.5	12.6	4.1	12.5	5.4	13.2	3.2	13.4	3.7
	May	12.8	4.0	11.8	3.2	12.9	3.4	12.8	3.8	11.8	3.3	12.2	4.4	11.4[41]	2.9[41]	12.8	2.9
	June	13.3	4.5	12.2	3.5	13.4	4.0	13.3	4.3	11.5	3.3	12.6	5.4	9.9[42]	2.7[42]	13.3	3.2
	July	12.8	4.5	11.1	3.4	13.9	4.2	12.9	4.4	10.6	3.4	11.3	5.3	10.5	4.5	12.8	3.7
	Aug.	13.6	4.0	11.4	3.6	14.2	3.7	13.9	3.9	11.3	3.2	12.9	5.0	11.6	3.6	14.0	3.3
	Sept.	13.9	4.5	12.3	4.2	14.0	4.3	13.3	4.0	12.1	3.8	13.4	5.4	12.1[43]	3.9[43]	13.9	3.7
	Oct.	14.6	4.7	13.4	4.2	14.3	3.9	14.6	4.0	9.6	2.9	13.4	5.4	11.3[44]	3.0[44]	14.2	3.4
	Nov.	13.1	4.2	12.3	3.8	11.4[45]	3.6[45]	12.9	4.1	8.2[46]	3.0[46]	11.9	5.5	—	—	13.3	3.4
	Dec.	10.3	4.8	9.9	4.2	9.9[47]	3.4[47]	9.6	4.3	5.6[48]	2.9[48]	8.7	5.8	—	—	11.2	4.4
1949	Av.	13.4	4.4	11.1	3.5	13.2	3.9	13.2	4.2	11.2	3.6	12.4	5.4	12.0	3.2	13.4	3.6

[27] Placed in service Aug. 11, with 2 rows of new plates in bays 2, 3, and 4; plates in bay 1 (4 rows) were placed in service June 18, 1945. [28] 1st, 2nd, and 11th–30th. [29] Placed in service Sept. 16, with new plates. [30] 17th–30th. [31] 1st–14th and 26th–31st; plates in bay 1 acid cleaned 16th–24th. [32] Out of service Dec. 7, 1948. [33] Nov. 1947–Dec. 1948. [34] Oct. 1947–Dec. 1948. [35] Sept. 1947–Dec. 1948. [36] Plates in effluent half badly clogged. [37] 22nd–31st. [38] 1st–18th. [39] 5th–31st. [40] 20th–30th, new plates in effluent half. [41] 1st–13th and 22nd–31st. [42] One influent gate closed, other set at ¾ open June 22; flow ¼ that to other tanks since. [43] 1st–12th and 17th–30th. [44] 1st–12th. [45] 1st–29th; air flow low in effluent half. [46] 1st–28th. [47] 2nd–15th; air flow low in effluent half.

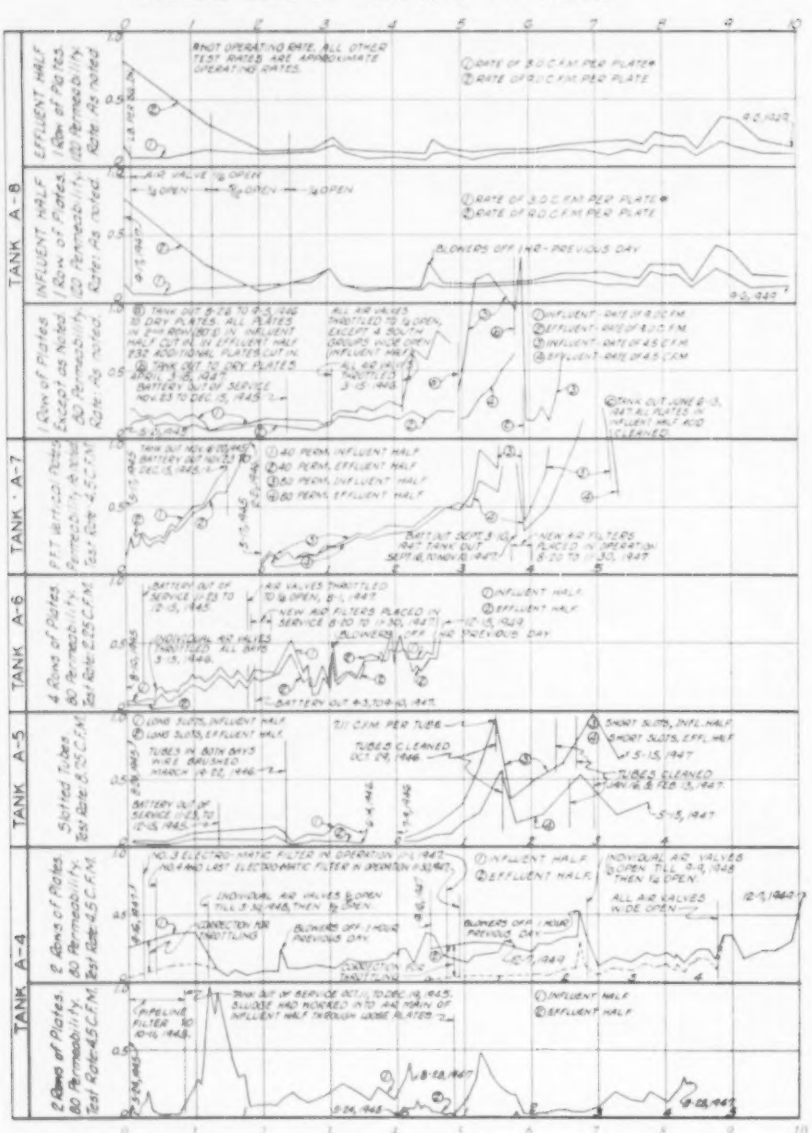

The Sanitary District of Chicago
Air Diffuser Tests at Southwest Sewage Treatment Works
PRESSURE LOSS VS VOLUME OF AIR PASSED
TANK A-8
TANK A-7
TANK A-6
TANK A-5
TANK A-4
TOTAL AIR PASSED PER DIFFUSER-MILLION CUBIC FEET.

FIGURE 1.

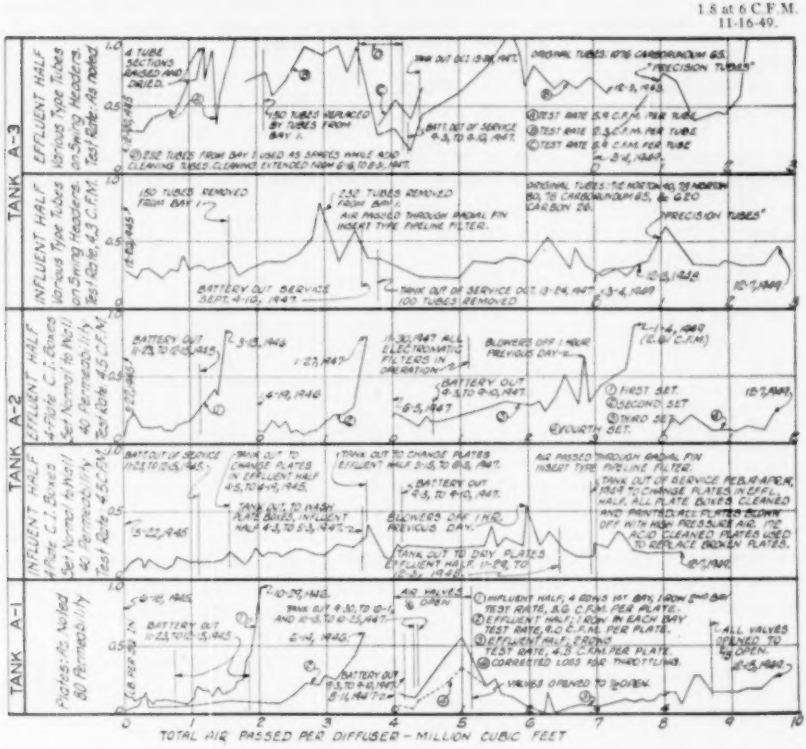

1.8 at 6 C.F.M.
11-16-49.
TANK A-3
EFFLUENT HALF
Various Type Tubes on Swing Headers. Test Rate, 4.3 C.F.M.
TANK A-2
EFFLUENT HALF
4 Plate C.I. Boxes Set Normal to Wall 40 Permeability
TANK A-1
Plates: As Valved 80 Permeability
TOTAL AIR PASSED PER DIFFUSER – MILLION CUBIC FEET

FIGURE 1 (Cont'd).

As air adjustments were not always perfect and the probable error in any one D.O. determination may be 5 to 10 per cent, results of short periods are not dependable. However, for periods of 6 to 12 months or more, such errors would be averaged out.

In analyzing the test data, tanks were compared in pairs over identical periods of 6 to 18 months in which the air distribution was reasonably uniform in each of the tanks. (Results from tanks after clogging diffusers had prevented uniform air distribution were not considered reliable.) In making the comparisons between two tanks, two methods were used for giving consideration to differences in the average D.O. of the mixed liquor, as follows:

1. Adjustments were approximated in the relative air requirements on the basis of the average undersaturations of dissolved oxygen. For example, during May 1946, tank A-8 had an average air rate of 10,400 c.f.m. and an average oxygen undersaturation in the mixed liquor of 7.8 p.p.m., whereas in tank A-4 the corresponding figures were 10,000 c.f.m. and 7.4 p.p.m. The relative quantity of air required in A-8 to produce the same dissolved oxygen as in A-4 was computed as:

$$10{,}400/10{,}000 \times 7.8/7.4 \times 100 = 110 \text{ per cent.}$$

2. The second method was to average for the period of comparison only the results of months in which the dissolved oxygen in the two tanks was

TABLE IV.—Comparison of Test Results from Various Diffuser Systems; Relative Air Requirements for Equal Dissolved Oxygen in Aeration Tanks 32.75 Ft. Wide by 15.5 Ft. Deep

No.	Period Compared	"First" Tank — compared to — "Second" Tank									Air Required "First" in Relation to "Second" Percent	Aver. D.O. for Period P.P.M.	
		Tank No.	Diffusers Description	Diffusers Installed	Diffusers Prior Service Months	Tank No.	Diffusers Description	Diffusers Installed	Diffusers Prior Service Months			1st Tank	2nd Tank
1	Jan 47–Sept 47	A2	One row Norton 80 plates	Nov 45	1	A3	Two rows Carb 40 plates	May 39	43		182	4.5	4.6
2	Sept 47–April 48	A2	" " " 120 "	Sep 47	1	A3	Carb 40 in 4 Containers*	(2)	48.39		182	4.3	4.4
3	Jan 45–May 45	A2	" " " 80 "	May 45	1	A3	" " " " "	May 45	1		107	3.9	3.5
4	May 45–Sept 45	A2	" " " 80 "	May 45	5	A3	" " " " "	(2)	18.5		107	4.1	4.3
5	Jan 45–Sept 45	A2	" " " 80 "	May 45	1	A4	Two rows Norton 80 plates	May 45	1		107	3.8	4.3
6	Sept 47–April 48	A2	" " " 120 "	Sep 47	1	A4	" " " " "	Sep 47	1		107	4.3	4.5
7	Sept 45–Sept 46	A2	" " " 80 "	May 45	5	A5	Four rows Norton 80 plates	Aug 45	1		116	3.9	4.2
8	Sept 47–April 48	A2	" " " 120 "	Sep 47	1	A6	" " " " "	Aug 45	28		127	4.3	6.1
9	Jan 46–Aug 46	A2	Two rows Norton 80 plates	May 45	5	A6	" " " " "	Aug 45	5		104	3.8	4.8
10	Sept 47–April 48	A2	" " " " "	Sep 47	1	A6	" " " " "	Aug 45	28		118	4.5	6.1
11	Jan 42–Sept 44	A7	Slotted pipe diffusers	Oct 41	14	A3	Two rows Carb 40 plates	May 39	43		173	4.4	4.3
12	Sept 44–Nov 47	A5	" " "	Aug 45	15	A6	One row Carb 40 plates One row Norton 80 plates	Nov 39 Nov 45	72 16		172	3.2	4.5
13	Sept 45–Jan 46	A5	" " "	Aug 45	1	A4	Two rows Norton 80 plates	Nov 45	4		138	3.7	4.5
14	Jan 42–Sept 44	A7	" " "	Oct 41	14	A4	One row Norton 80 plates	Oct 42	2		135	4.0	4.1
15	Sept 45–Jan 46	A5	" " "	Aug 45	1	A6	" " " " "	Nov 45	4		135	3.7	3.9
16	Sept 45–Jan 46	A5	" " "	Aug 45	1	A6	Four rows Norton 80 plates	Aug 45	1		150	3.7	4.1
17	Jan 46–Jan 47	A3	Porous Tube Swing Diffusers	Dec 45	1	A6	" " " " "	Aug 45	5		112	3.9	4.6
18	Jan 46–Jan 47	A3	" " " "	Dec 45	1	A4	Two rows Norton 80 plates	May 45	8		108	3.9	4.6
19	Jan 46–Jan 47	A3	" " " "	Dec 45	1	A5	One row Norton 80 plates	May 45	8		100	3.9	3.9
20	Jan 45–Sept 46	A7	Vertical Carb 40 plates (RT)	May 45	1	A4	Two rows Norton 80 plates	May 45	1		127	3.4	3.4
21	Jan 46–May 47	A7	Vertical Norton 80 plates (RT)	May 45	1	A4	" " " " "	May 45	13		142	4.8	4.4

Notes: Vertical plates and porous tubes at 13 and 13.5 feet depth, respectively. All other diffusers at 15 feet.
* In 4 plate containers normal to wall. Equivalent to two rows.
(a) New plates in Boys I and 2, May 45; returned plates in Boys 3 and 4, June 47.
(b) New plates in Boys I and 2, May 45; in Boys 3 and 4, Apr 46.

practically the same. The results obtained by the two methods agreed very closely.

A study of the summary of results of the comparison by pairs of tanks, through 1947 (Table IV), indicated two factors that were significant in subsequent comparisons:

1. There appears to be no difference in the air economy of diffuser plates of different permeability within the range tested of 40 to 120. This is apparent by comparing lines 1 with 2 and 3, and 5 with 6 (Table IV). For the same diffuser arrangement, changes in permeability of plates did not appear to alter the relative air requirements of any two tanks, where the plates had been in service about the same length of time.

2. There was an improvement in air

TABLE V. Summary of Relative Air and Power Requirements for Equal Dissolved Oxygen in Aeration Tanks with Various Diffuser Systems [1]

Diffuser System	Diffusers in Tank	Depth to Diffusers (ft.)	Relative Air (%)		Relative Power[2] (%)	
			New Diffusers	Diffusers in Service Yr. or More	New Diffusers	Diffusers in Service Yr. or More
4 rows porous plates	5,640	15.0	110	100[3]	110	100[3]
2 rows porous plates	2,820	15.0	115	104	115	104
1 row porous plates	1,410	15.0	124	112	124	211
Porous plates in cast-iron containers, normal to wall	2,730	15.1	115	104	116	105
Porous tubes (swing)	2,552	13.5	124	112	115	104
Vertical porous plates	2,720	13.0	147	—	132	—
Slotted brass tubes	1,410	15.0	170	170	170	170

[1] Rate of air application was about 12 c.f.m. per 1,000 cu. ft. of tank for 4 rows of porous plates. For other systems proportionally higher.

[2] Making allowance for difference in air pressure due to depth of submergence.

[3] Arbitrarily taken as 100 per cent for comparison.

economy of porous diffuser plates after prior service of about a year or more. This is apparent by comparing line 7 with 8, 9 with 10, 13 with 11 and 12, and 20 with 21. The air required for new porous plates appears to exceed that for old plates by about 10 per cent. It is assumed that this would apply to porous tubes, as well as plates, although there was not a sufficient period for confirmation. In subsequent comparisons, porous tubes are given the benefit of this assumption.

The results shown in Table IV are further summarized (Table V) to show the air economy in relation to the characteristics of the different diffuser systems. Also in Table V, theoretical relative power requirements have been shown on the basis that advantage could be taken of lower air pressure due to less submergence of the diffusers where it was different from 15.0 ft. The significant factors indicated by this comparison are as follows:

1. Air economy improved with greater numbers of diffusers. The relation appears to be about as follows:

Rows of Plates	Plate Ratio	Relative Air Requirement (%)
4	1:10	100
2	1:20	104
1	1:40	112

This becomes the most important factor in a design comparison to determine the economical number of diffusers to be used.

2. Porous tube diffusers probably would have about the same air economy as a like number of horizontal porous plates if operated at the same submergence. The possible power saving of reduced submergence is offset by the greater quantity of air required.

3. Vertical porous plates show less air economy than plates in horizontal position.

4. Slotted tube diffusers are considerably inferior to porous diffusers in air economy.

Analysis of Data for Relative Clogging Rate

The net pressure loss through the diffusers for each half of each test tank and for each set of diffusers in the respective tanks was plotted against the total amount of air passed per diffuser. This complete graphical summary is given in Figure 1, together with notes on conditions affecting pressure losses. A study of these curves makes it possible to identify and approximately evaluate some of the factors affecting diffuser clogging.

Effect of Air Rate

In Figure 2 the pressure losses for the effluent halves of tanks A-6, A-4, and A-8 have been plotted in two different ways. Figure 2a shows pressure losses plotted in relation to actual time; Figure 2b, in relation to the total amount of air passed, as in Figure 1. The three curves in each case represent the rates of clogging for the same make of 80-permeability porous diffuser plates operated concurrently at average rates of approximately 2, 4, and 8 c.f.m. per diffuser plate, respectively.

The data for the 2-c.f.m. rate, tank A-6, are somewhat unsatisfactory because it was discovered that sludge had accidently been allowed to get under the plates through open drain plugs, probably increasing pressure losses. Pressure losses in tank A-4, 4-c.f.m. rate, would be expected to run somewhat higher than in A-8 because losses were generally higher near the influent end of the battery, as discussed later. In tank A-8, plates were replaced after pressure losses exceeded the operating range; in A-4, plates were replaced during a replacement contract because it was considered desirable at the time to avoid loss of treating capacity at a later critical period; and in A-6, the plates are still in operation.

Comparison of Figures 2a and 2b makes it apparent that time in itself has little if any effect on the clogging of diffusers; but that the total amount

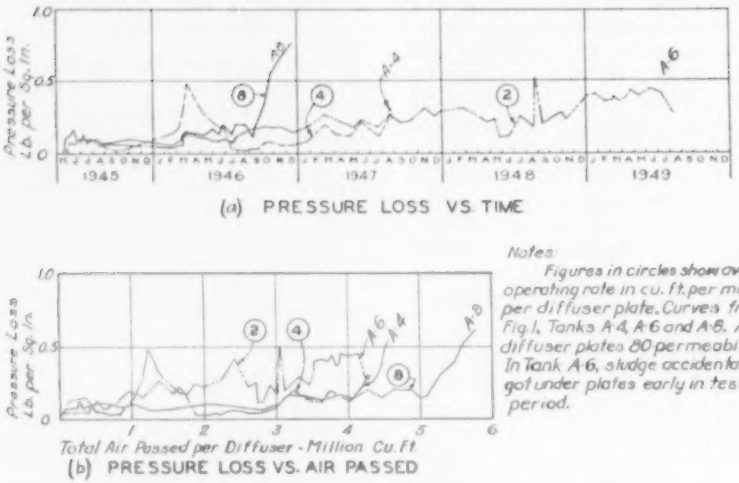

Pressure Loss Lb per Sq. In.
1.0
0.5
0
A2
A4
A6
8
4
2
1945
1946
1947
1948
1949
(a) PRESSURE LOSS VS. TIME
Notes:
Figures in circles show average operating rate in cu. ft. per minute per diffuser plate. Curves from Fig. 1, Tanks A-4, A-6 and A-8. All diffuser plates 80 permeability. In Tank A-6, sludge accidentally got under plates early in test period.
A8
Total Air Passed per Diffuser - Million Cu. Ft.
(b) PRESSURE LOSS VS. AIR PASSED

FIGURE 2.—Effect of air rate on clogging rate of porous diffusers.

of air passed per diffuser, regardless of rate, gives a consistent measure of the diffuser life. Another comparison would be New York's Bowery Bay plant, where the diffuser plates have passed about 13,000,000 cu. ft. of air in 7 years of service at a rate of 3.5 c.f.m., against Chicago's North Side plant, where the diffuser plates, after about 21 years of service, have passed 11,000,000 cu. ft. of air at a rate of 1 c.f.m.

It was concluded that, other conditions being the same, the life of a porous diffuser before clogging to its permissible limit is determined by the total amount of air passed, rather than by the length of time in service. There are indications that this may be further extended to the total amount of dust in the air passed, where clogging is due primarily to this cause, but data are still meager on this point.

Effect of Dust in Air

The importance of adequate air filtering is illustrated by Figure 3, showing the pressure loss curves for tank A-2, in which the air supply to the influent half of the tank was given secondary filtering by means of pipeline filters, whereas the effluent operated on the general plant air supply with only viscous filters until Novem-

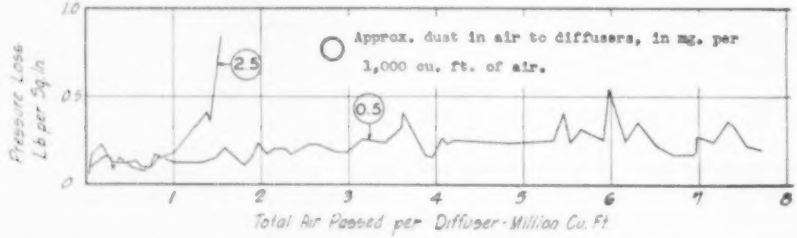


FIGURE 3.—Effect of dust in air on clogging rate of porous diffusers (Curves from Figure 1, tank A-2, 40-permeability porous plates).

ber, 1947. The diffusers for both halves were 40-permeability porous plates operated at about 4 c.f.m. Dust determinations, made by the Trostel and Frevert (2) method with modifications by A. J. Beck, showed an average of approximately 2.5 milligrams per 1,000 cu. ft. of air to the effluent half and 0.5 mg. or less to the influent.

Plates operating on the 0.5-mg. air have already operated five times as long as the plates operating on 2.5-mg. air. Results from tank A-3 (porous tubes on swing diffusers), with the same secondary filtering on the influent half, show similar results.

The tests indicate that porous diffusers act as air filters and become clogged by the dust removed from the air. It is probable that the life of a porous diffuser, other conditions being the same, is inversely proportional to the amount of dust in the air.

Effect of Permeability

The pronounced effect of the permeability rating on the clogging rate of porous diffusers is shown by Figure 4. The pressure-loss curves for 40- and 80-permeability plates operated consecutively in vertical position in tank A-7 are shown in Figure 4a. That is, after the 40-permeability plates clogged, they were replaced by 80-permeability plates.

In Figure 4b, the pressure-loss curves for the effluent halves of tanks are compared. The 65-permeability porous tubes operated on the swing diffusers had a pore size approximately equal to the 40-permeability plates due to the difference in thickness of the porous media; but showed somewhat faster clogging rate than the 40-permeability plates. The two curves for 40-permeability plates represent the first and second consecutive sets of plates in tank A-2. The curves for 80-permeability plates are for tanks A-1, A-4, A-6, and A-8. The curve for 120-permeability plates, tank A-8, is not comparable because it represents operation after electronic filters had been installed on the plant air supply, reducing the dust content to about 1.0 mg. per 1,000 cu. ft. All the other curves are for operation on air averaging about 2.5 mg. per 1,000 cu. ft.

From an inspection of the curves, it is apparent that the 40-permeability plates clogged approximately twice as fast as the 80-permeability plates, and

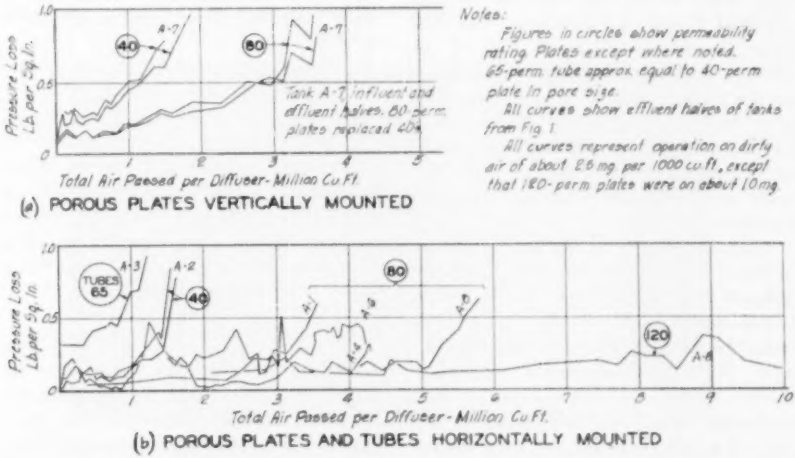


FIGURE 4.—Effect of permeability on clogging rate of porous diffusers.

it appears likely that the 120-permeability would show a proportional improvement. It is probable that, other conditions being the same, the clogging rate of porous diffusers is inversely proportional to the permeability rating.

It should be noted that the decrease in clogging rate with increased pore size did not apply to the slotted diffusers. These brass tubes with 0.04-in. slots clogged about as rapidly as 80-permeability porous plates. Also, in a previous trial of perforated clay plates with 0.027-in. holes, the clogging rate was at least as rapid as 40-permeability plates.

Effect of Location

The pressure loss curves (Figure 1) for all the test tanks which operated on the same quality air show faster clogging in the influent half. There are insufficient data to indicate whether there is a gradual change in clogging rate throughout the length of the tank or a fairly definite change at some point in the length. Although the cause is not known, it could be one or a combination of effects such as fine silt, precipitate from the sewage, or organic growths. However, the fact that clean air in the influent half of tanks A-2 and A-3 increased the diffuser life to several times that of the effluent half of these tanks casts doubt on the importance of any surface clogging effects. Regardless of the cause, the diffusers in the effluent half of the tanks would give 10 to 30 per cent more service before reaching the same pressure loss.

There was also a definite increase in the diffuser losses in tanks near the influent end of the battery. Both the mixed liquor and the air supply feed from the tank A-1 end, A-8 being the last. With the same make 80-permeability plates and the same average operating rate, the diffusers in A-8 showed a life some 50 per cent longer than in A-1. This could be explained by cleaner air to A-8 resulting from dust particles adhering to the inside of the large air mains in the operating gallery. It was computed that the amount of dust removed by a deposit of only 0.0003-in. thickness per year could account for the difference in clogging rate.

Effect of Organic Growths

A fungus growth appears to be present on the surface of operating diffusers at the Southwest plant at all times. The amount of this growth increases with warmer sewage and is heaviest at the influent ends of tanks. However, it has had little effect on pressure losses, except in the summer of 1944 just prior to the major comparative tests. At that time, the offending growth was identified as *Saprolegnia*, a water mold fungus. The source of the fungus was not found.

Incomplete Comparative Tests

As noted in Table 1 and Figure 1, some of the diffuser systems have not reached the limit on clogging. Two of the recently installed modifications have not operated long enough to afford reliable data on either air economy or clogging, although some indications to date on the latter are worth noting.

"Precision" Tubes

In tank A-3, with swing diffusers, the porous tubes were replaced by "precision" tubes in March, 1949. Data through December, 1949, indicate air economy about equal to porous diffuser tubes. However, their clogging rate appears to be several times faster than porous tubes.

Porous Tubes at 15-ft. Submergence

In tank A-5, porous tubes were installed in place of the slotted diffusers at 15-ft. submergence in January, 1949. These tubes were removed from tank A-3 (swing diffusers) and acid

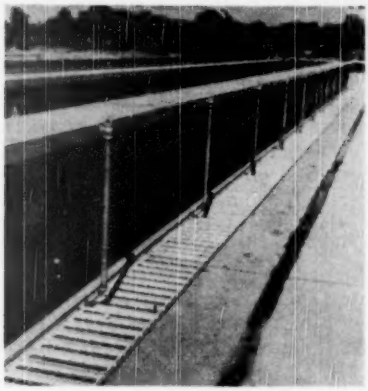


FIGURE 5.—Air diffuser system of battery C before placing mortar under holders and over pipe headers.

cleaned before placing in A-5. Due to the location of the stationary pipe headers in A-5, half of the tubes were set parallel to the tank wall by means of pipe fittings. Data through December, 1949, indicate air economy about equal to a like number of porous plates at the same submergence.

Application of Results

The object of the diffuser testing by the Sanitary District was to obtain reliable data as a basis for its design. The results have been applied to the design of the diffuser system for Battery C at the West-Southwest sewage treatment works, placed in operation in December, 1949. This addition to the plant has a capacity of 300 m.g.d., raising the plant total to 900-m.g.d. average flow. The salient points of this design, adopted after economic studies based on the test results to determine the lowest total annual cost, are as follows:

1. An entirely new air filtering system is being installed for the entire plant, consisting of bag filters with loose asbestos fiber lining for primary filtering, and automatic electronic filters for secondary filtering. This is expected to reduce the unusually dirty raw air at the plant from a dust content of about 9.0 mg. to less than 0.5 mg. per 1,000 cu. ft.

2. The diffusers are 80-permeability porous plates, except that one of the 8 tanks is being equipped with 120-permeability plates. This was done because of the demonstrated merit of the 80's for this plant, and to check further the more favorable indications for 120's.

3. The diffuser plates are cemented into 6-plate precast concrete holders

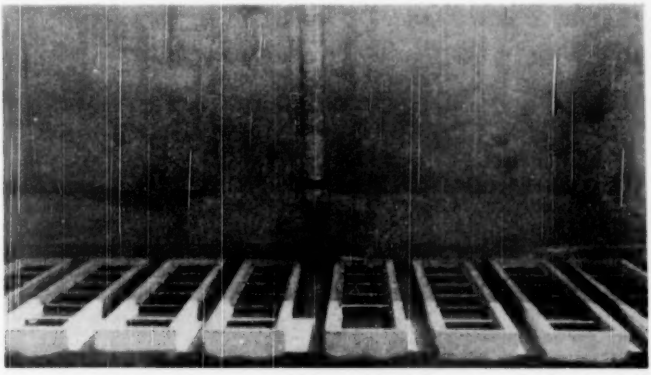


FIGURE 6.—Air diffuser system of battery C with holders bedded in mortar and pipe header covered with mortar finished to make a smooth slope joining into the bottom fillet of the tank wall.

because the computed long life with clean air and high-permeability plates indicated an annual cost on a replacement basis less than for removable diffuser mountings and periodic cleaning.

4. The plate holders are placed normal to the tank walls and connected into 4-in. headers about 34 ft. long by means of $\frac{3}{4}$-in. right- and left-hand stainless steel nipples. Each pipe header is supplied by a 6-in. riser at the center. This arrangement was adopted to provide good air distribution to the plates tributary to one 6-in. valve, to reduce the amount of piping, and to provide advantageous placement of diffusers in the tanks.

5. There are 4,728 diffuser plates per tank (equivalent to about 3.4 rows), making the plate ratio 1:11.7, and an average operating rate of about 3 c.f.m. per plate. This was determined by balancing first cost against air requirements and replacement costs to determine the economical number.

6. There is a 27 per cent greater concentration of diffuser plates in the influent half of the tanks than in the effluent half, in order to obtain a uniform life or rate of clogging throughout each tank. This makes the plate holder spacing $22\frac{3}{4}$-in. center to center in the influent half and 30 in. in the effluent half of the tanks.

Figures 5 and 6 show the diffuser system described above in various stages of construction.

Acknowledgments

The design and research work on sewage treatment for The Sanitary District of Chicago is under the direction of W. A. Dundas, General Superintendent; W. H. Trinkaus, Chief Engineer; H. P. Ramey, Assistant Chief Engineer; Langdon Pearse, Sanitary Engineer; F. W. Mohlman, Director of Laboratories; and the author, as Engineer of Treatment Plant Design. Operation of the major plants is, respectively, under the direction of A. H. Goodman at West-Southwest, J. R. Palmer at North Side, and C. E. Wheeler, Jr., at Calumet, all of whom contributed suggestions and information for the experimental work. C. T. Mickle, Assistant Civil Engineer under A. H. Goodman, was in direct charge of the diffuser operating tests and was assisted by J. D. Farquhar and C. V. Erickson, Assistant Civil Engineers, and R. J. Scott and D. G. Storey, Junior Civil Engineers. Air cleanliness determinations and air filtering experiments were conducted by A. J. Beck, Principal Sanitary Chemist. T. L. Herrick, Assistant Civil Engineer, compiled, coordinated, and summarized the test data. H. R. King, Senior Civil Engineer, did much of the work on data analysis. Norman Dawson, Assistant Engineer of Treatment Plant Design, assisted in the preparation of designs and economic comparisons. Also, credit should go to the several co-workers who assisted in the experimental work and presentation of results, and to associates for their criticisms.

References

1. Becker, H. G., "Mechanism of Absorption of Moderately Soluble Gases in Water." *Ind. and Engr. Chem.*, **16**, 1215 (1924).
2. Trostel, L. J., and Frevert, H. W., "Collection and Examination of Explosive Dusts in Air." *J. Ind. Engr. Chem.*, **5**, 232 (1923).

DISCUSSION

By John J. Wirts

Assistant to the Commissioner of Utilities Engineering, Cleveland, Ohio

During the past several years, literature on the subject of air diffusion for activated sludge has appeared in most of the publications concerned with sanitary engineering. The information is voluminous and is cluttered with papers, advertising, and editorial comment slanted, perhaps unconsciously, towards the wishful thinking of the authors. Perhaps the writer, also, may have been guilty of this charge.

The old ideas persist along with the new observations; they form the basis —often unconsciously—for many of the conclusions that are drawn.

Not many years ago a superintendent, now retired, of a well-known Eastern plant, introduced a method for improving the distribution of air in the activated sludge process. His new method was called the "hammer treatment," and consisted of the proper application of a hammer to the top center of a square air diffuser plate. The neat crack resulting from the hammer blow allowed the free passage of air into the starved mixed liquor, completely restoring it to life and vitality. That an abundant air supply is essential for the growth and oxidizing capacity of activated sludge is unquestioned; it was the method of allowing the air free passage around the installed diffusers that was nonsense. If this illustration seems extreme and not apropos of the subject under discussion, it should be recalled that a number of plants are using perforated pipes to alleviate clogged diffuser media.

An examination of more recent work appearing in the *Sewage Works Journal* should be helpful in demonstrating how the feelings of authors, not facts, may cloud the issues of science. As an example, the following statement appeared as the only supporting evidence for sweeping claims to promote the use of certain equipment: "Actual tests on a plant scale are difficult to evaluate numerically because of inequality factors, but they have generally corroborated laboratory results and proved the expected operating advantages." In the absence of any pertinent technical data even the most naive should realize the unsupported nature of the article. It is unnecessary to consider a semantic analysis of the phrase "expected operating advantages."

It is indeed refreshing to find, as in Mr. Anderson's paper, a well documented presentation of the subject of air diffusion and to receive excellent reports containing valuable data that have added materially to the knowledge of the subject.

The vast amount of work that was necessary in order to carry out this study is impressive. Very few organizations have the wisdom, not to mention, manpower, facilities, and money to produce a finished treatise on this important subject. It is predicted that the savings in cost of air diffusion as it relates to the Chicago problem will "pay off" many times over for the investment made in the purchase and testing of all well-known types of air diffusion equipment by The Sanitary District of Chicago. Experience in Cleveland in developing maintenance procedure and trying to operate large-scale units on a pilot plant basis makes for appreciation of the tremendous amount of work that was necessary, and also the limitations of that work.

The Chicago work followed two general lines of investigation—

the determination of the most economical method of design of air diffusion equipment, and

a study of these factors affecting clogging of air diffusion media.

Relative Air Economy Data

The theory of air economy as stated by Mr. Anderson, that the same D.O. in the effluent would indicate equal oxygen utilization in the test tanks and that the quantity of air required to produce this D.O. in each tank would indicate the relative air economy of the respective diffuser systems, seems to be very sound. The test conditions as outlined appear to be proper. Just how close to perfection the adjustment of air was, and how uniform the air distribution was, is difficult to evaluate. Certain of the monthly average D.O. data varied from 2.6 to 5.3 p.p.m. in comparative tanks under test. In general, however, the control of the dissolved oxygen can be considered quite uniform.

The analysis of the test data (Table V) comparing pairs of tanks conclusively proves one very important point —that there appears to be no difference in the air economy of diffuser plates of different permeability within the range tested of 40 to 120. This is new.

The submergence factor associated with porous diffuser tubes can no longer be considered an advantage from the standpoint of over-all economy. Diffuser tubes mounted as swing diffusers for the smaller plants still have their obvious advantages.

Relative Clogging Rate

The paper states, "It was concluded that, other conditions being the same, the life of a porous diffuser before clogging to its permissible limit is determined by the total amount of air passed." From other reports, Mr. Anderson recognizes the possibility of serious surface clogging, which fortunately is not a problem at the Southwest works.

The history of air diffusion at Cleveland definitely proves that the surface clogging is a major factor. Only 3,500,000 to 4,000,000 cu. ft. of air per plate can be passed before the head loss becomes excessive. Analysis of the air after two stages of filtering indicates a dust content of less than 1.0 mg. per 1,000 cu. ft. Therefore, the life of a porous diffuser before clogging to its permissible limit, related to Cleveland, is not determined merely by the total amount of air passed. It is determined by the total amount of air passed and some factor representing the difference in mixed liquor content between Cleveland's analysis and Chicago's analysis. Experiment will determine if the excessive iron and heavy metal content are the source of Cleveland's short diffuser life.

Qualitative comparative tests at Cleveland's Easterly plant on a combination plastic and metal diffusion tube indicate a higher rate of clogging than for plates used in the same aeration tank.

The work done in Chicago is unquestionably an outstanding achievement in the analysis of a vexing problem. Available now for the first time are some of the fundamental relationships in air diffusion, backed by comprehensive and accurate data.

SEWAGE WORKS DEVELOPMENT IN THE MASSACHUSETTS METROPOLITAN DISTRICT *

By Karl R. Kennison

Chief Engineer, Construction Division, Metropolitan District Commission, Boston, Mass.

Briefly stated, the pollution problems of the Massachusetts Metropolitan District have arisen principally from two general causes or conditions—the discharge into Boston Harbor of raw sewage from a population of 2,000,000, and the overflow into tributary basins of mixed sewage and storm water from overtaxed sewers. The sewage pollution of the harbor itself is from three main sources: the outfall of the Boston Main Drainage System, where prior to the organization of the Metropolitan District with its two sewerage systems, the City of Boston commenced in 1884 to discharge its sewage on the outgoing tide off the shore of Moon Island; the outfall of the South Metropolitan Sewerage System at Nut Island; and the outfall of the North Metropolitan Sewerage System at Deer Island.

Harbor and Tributary Pollution

The three main sewage outlets release into Boston Harbor an average of 275 m.g.d., with low-flow discharge of about 150 m.g.d. and peak discharge of nearly 700 m.g.d. The 275-m.g.d. flow is divided roughly about 75 off Moon Island, 100 off Nut Island, and 100 off Deer Island.

In addition, a temporary station on the North Metropolitan System pumps an average of 20 to 25 m.g.d. into Chelsea Creek, an estuary tributary to the inner harbor. This average sewage discharge, if thoroughly mixed with the water entering and leaving the harbor between tides, would be diluted about 550 times. Based on expected capacities, the ultimate peak discharges will be increased to about 1,100 m.g.d., divided into 200 off Moon Island, 350 off Nut Island, and 550 off Deer Island.

Legislative Investigations

The matter of the pollution of Boston Harbor and its tributary streams has been under investigation by the State Department of Public Health and by the General Court (Legislature) for many years. In June, 1939, a special legislative commission made detailed investigations of the problem. The present clean-up program was recommended in the report of this special commission.

The General Court took steps to put these recommendations into effect by legislation that took final shape in Chapter 720 of the Acts of 1941, which named five projects to be carried out by the former Metropolitan District Water Supply Commission as enlarged for the purpose of this sewerage construction, which Commission later (July 1, 1947) became the Construction Division of the Metropolitan District Commission. The consulting engineers of the special commission continued their studies and made their final report January 1, 1941. The five projects then named by the Legislature were as follows:

1. Sewage treatment plant at Nut Island.
2. Extension of North Metropolitan

* Presented at 22nd Annual Meeting, Federation of Sewage Works Associations; Boston, Mass.; October 17–20, 1949.

relief sewer from new East Boston pumping station to Deer Island.

3. Alewife Brook storm overflow conduit and pumping station.

4. South Charles storm overflow conduit and pumping station.

5. North Charles storm overflow conduit and pumping station.

General Plan for Sludge Disposal

After studying the requirements of a sewage treatment plant at Nut Island, the Commission's engineering organization concluded that the most practicable and probably the most economical method of disposing of the sludge from any and all future treatment plants around Boston Harbor would be to discharge digested sludge through deep-sea outfall pipes. The principal reasons for rejecting the alternate plan of barging raw sludge to sea were its lack of dependability, the equipment being subject to weather and other hazards, and the high maintenance and operating costs involved in such marine operations.

Because of the reduction in volume, the outfall lines required for digested sludge are surprisingly small. The over-all plan as developed for present and future sludge disposal contemplates the discharge from all treatment works into a most desirable location in the deepest outlet from the inner harbor, President Roads, which is about 60 ft. deep at low tide and remote from all the more important recreational beaches. The only sludge outfalls required are a 12-in. submarine pipe across the harbor from the Nut Island site to a junction at the south end of Long Island with a 10-in. line from the Calf Pasture site, and an extension from this junction point along the shore of Long Island to deep water on the south shore of President Roads. This will take care of the plants on the South Metropolitan and Boston Main Drainage Systems. For the North Metropolitan System no separate outfall for digested sludge will be required, as that main effluent outfall is already very favorably situated on the north side of President Roads and it will be necessary only to add the digested sludge to the plant effluent.

Enlargement of Projects

As the result of detailed studies by the Commission's engineering organization, not only were changes made in the preliminary designs, in collaboration with the consulting engineers, but a comprehensive over-all plan was proposed involving major changes in Projects 2, 3, and 4 in the interest of over-all present and future economy. The result of this is shown in the following restatement of the enlarged projects and their estimated costs.

Project No.	Project Description	Estimated Cost
1	Sewage treatment plant at Nut Island	$ 6,750,000
2	Extension of North Metropolitan relief sewer to Deer Island	10,800,000
	Treatment plant at Deer Island	6,000,000
3	Alewife Brook interceptor and pumping station	2,000,000
4	Interceptor along South Charles and from Boston marginal conduit	6,735,000
5	Interceptor along North Charles	1,200,000
Below junction of Projects 4 and 5:		
	Subaqueous conduit in Charles River Basin, and emergency pumping station	3,500,000
	Tunnel, Charles River Dam to Chelsea Creek	3,015,000
	Total	$40,000,000

In most instances the sums have been authorized by the most recent act of the Legislature, Chapter 606 of the Acts of 1949. The legislation, in spite of the over-all authorization, placed restrictions on the actual construction by limiting the annual expenditure.

Progress to October, 1949, on the various projects has been as follows:

Project 1

The existing works at Nut Island are at the end of the South Metropolitan trunk sewer with a capacity of 300 m.g.d. A present average of approximately 100 m.g.d. of raw sewage is discharged continuously through two 60-

in. outfall pipes, emptying about 6,000 ft. from the shore. A third 60-in. pipe discharging only 1,400 ft. offshore is available at times of high flow. The existing plant consists of a single building where the larger solids are removed by manually cleaned racks of the cage-elevator type, the removal being rather ineffective. The existing rack house is on what was originally an island about ⅓ mile offshore.

In creating the site for the new plant about 250,000 cu. yd. of sand and gravel were hauled to the site from borrow pits, supplemented by about 75,000 cu. yd. of excavation at the site. All the foundation work for the main plant has been completed, including all underground tanks and other such structures.

The 12-in. digested sludge outfall pipe to deep tidewater has been completed. The Long Island shore portion was laid with mechanical joints, the submarine pipe being laid with Victaulic joints. The trench was first excavated by grab bucket, the material being removed in scows. The bottom of the trench was then graded by laying a long steel H-beam on the bottom while the diver used a water jet to sluice the material to grade.

Six lengths of pipe (72 ft.) were assembled on the barge deck and slung under a strong-back constructed of two 6 × 6 × ½-in. angles 64 ft. long with supports 12 ft. apart. The strong-back was equipped with adjustable wooden saddles to hold the pipe to a straight alignment, or to any predetermined horizontal curvature. To make the underwater joint, a collapsible steel cone projecting about 8 in. from the end of the assembly on the barge was expanded to hold it firmly inside the pipe, with a trigger arrangement permitting it to be inserted in place after the strong-back was lowered to final position, and collapsed and removed by the diver pulling on a cable threaded through the entire length of the pipe assembly.

The contract for submarine work included the placing of diffusers over the outlets of the two existing main 60-in. outfall pipes, which now discharge the raw sewage about 6,000 ft. offshore, and which will be used to discharge the clarified effluent from the sedimentation tanks. The construction of these diffusers is covered more fully hereinafter in connection with the description of the various details of design of the Nut Island treatment works.

Practically all equipment for the Nut Island plant was purchased at an early date and now stored in temporary buildings at the site, for fear that late deliveries might hold up completion. Some $4,700,000 of the estimated $6,750,000 worth of work in this project has been completed or is in process of construction.

Project 2

At present, sewage of the North Metropolitan District is carried to Deer Island through the original sewer by pumping at East Boston. In 1941 the old trunk sewer from Reading to East Boston was supplemented by a much needed relief sewer. This was extended as far south as Chelsea Creek, where a siphon of 3 parallel 60-in. pipes was built under the Creek to East Boston. The need for extending this relief sewer to Deer Island has been an urgent one for many years.

The original plan for extending the sewer to Deer Island included the use of the two pipe siphons under Chelsea Creek. The present comprehensive plan for relief of the South Metropolitan by tunneling all the way through from Charles River Dam leaves no economic justification of retaining the siphon for this purpose. Accordingly, a contract is being prepared for sinking the tunnel shaft on the Chelsea side of the Creek. How this fits into the comprehensive plan is described in greater detail under Projects 4 and 5.

At the Deer Island end of the tun-

nel the location of the shaft is still undetermined because of the possibility of acquiring real estate from the Federal Government. Although the extension of the relief sewer involves only the necessary additional pumping requirements at the Deer Island end, these must be coordinated with the entire plan for a sewage treatment plant at this point. Hence, the location and the details of design of the structures at the Deer Island end of the tunnel must wait until the major features of the entire sewage treatment plant are satisfactorily determined. Nevertheless, a start can soon be made by constructing the tunnel shaft at Chelsea Creek. Soon thereafter it should be possible to proceed with the shafts at the Charles River Dam and Deer Island, so that there will be no delays in the tunnel construction to connect them.

Preliminary plans for the Deer Island sewage treatment plant are based on a design rate of about 145 m.g.d., with a maximum capacity of 350 m.g.d. Flows in excess of this, up to the overall maximum pumping capacity of 535 m.g.d. will be by-passed directly to the outfalls. The existing outfall is an excellent one with 14 multiple outlets in the last 115 ft., at from 32 to 48 ft. below low tide. This outlet will carry all the effluent under ordinary conditions, having a capacity of between 160 m.g.d. at high tide and 250 m.g.d. at low tide. There is also an old offshore outlet, well located at the tip of the island, that could be put back into service if desired to add about 60 m.g.d. to the capacity at high tide. A new offshore outlet will have to be provided. It will be so designed, however, that nothing but the plant effluent will pass through it and the entire 185 m.g.d. of mixed sewage and storm water that must by-pass the treatment plant at the peak pumping capacity will pass through the old outfalls, including the excellently situated multiple outlets.

Project 3

The existing Alewife Brook conduit consists of one 30-in. and one 15-in. branch from the Belmont line and one 18-in. branch from a point near Fresh Pond. These join in a 23 × 33-in. sewer that increases in size to 35 × 42-in. as it follows down the stream to a pumping station, which pumps through a 36 × 43-in. force main into the already overtaxed North Metropolitan sewer. The connections it has been necessary to make in working out the design of the new line, which was originally intended to serve as a storm overflow sewer, are such that to all intents and purposes the new line is merely a supplementary sanitary sewer of substantially increased capacity so that when the North Metropolitan relief sewer is extended as planned to Deer Island, the storm overflows will be reduced substantially. In all important features the construction follows the plans of the consulting engineers, which were based on a dilution factor of 10. Here, as in the case of Project 1, the actual construction has progressed somewhat slowly on account of the limits set in the appropriation of funds. About 10,000 ft. of a total of 18,000 ft. of pipeline have been constructed. The remainder is under construction and the equipment has been purchased for a new pumping station, which will be built in the rear of the present pumping station without interruption in its operation.

The completed line will start near Fresh Pond with a 48-in. diameter precast reinforced concrete pipe. The connecting branch from the Belmont line is of 36-in. diameter. Below the junction, the new line is 66 in. in diameter to its connection with the North Metropolitan relief sewer. The new pumping station is designed so that at all times about 12 m.g.d. of the inflow is pumped separately through the old force main to the North Metropolitan sewer. The remainder, up to about 35 m.g.d., may pass through the sta-

tion by gravity, necessitating a surcharge on the line upstream. When the total flow exceeds 47 m.g.d. the entire amount will be pumped, 12 m.g.d. to maintain the flow in the old force main and the remainder through the new Alewife Brook conduit to the North Metropolitan relief sewer. In this way the high rates of flow will be automatically pumped by the 3 variable-speed units so as to prevent overflows into the brook. The station will be automatic.

Project 4

The existing Charles River sewer starts at the Waltham line, 42 × 48 in. in size, and extends along the south bank of the Charles to the Ward Street pumping station, increasing in size en route to 72 × 78 in. The first proposal of the consulting engineers was to reinforce this with a sewer extending all the way from the upper end and continuing along the Charles River Basin to tidewater below the Charles River Dam, involving a large booster pumping station en route, and also included an additional line south to the Ward Street pumping station; increasing the capacity in the Ward Street station; and adding a new force main to the high level South Metropolitan sewer. Subsequently, they also proposed that instead of reinforcing the line to and through the Ward Street pumping station it would be better to provide a future connection to divert excess flows from the South Metropolitan to the North Metropolitan sewer at East Boston and thence to Deer Island. In fitting Project 4 into the comprehensive plan as now designed, such a diversion to the North Metropolitan will be made by constructing a submarine conduit serving both sides of the basin and discharging into a shaft at the Charles River Dam, thus avoiding the necessity of an expensive new line along the south shore to the Charles River Dam and eliminating also the Berkeley Street pumping station. Further studies also indicated the possibility of a complete diversion of the old Charles River Valley sewer and of all sewage now discharged through Ward Street pumping station so as to eliminate also the operation of that station.

Project 5

The existing Cambridge sewer starts from the Belmont line and extends along the north bank of the Charles River to a pumping station at the Mystic River bridge. The plan as originally proposed by the consulting engineers included a supplementary sewer along the north bank of the basin to a new pumping station, and would discharge below the Charles River Dam. Subsequent studies have indicated that overflows from the Cambridge marginal conduit into the lower end of the basin can be satisfactorily controlled with the existing works. Accordingly, in adapting Project 5 to the comprehensive sewerage plan the expense of a new conduit along the north side of the lower basin and a new pumping station has been eliminated. The design makes a practically complete diversion into the new works from the old Cambridge sewer, not only effectively lowering the gradient to prevent overflows into the basin, but also providing much needed relief of the old pumping station under the Mystic River bridge.

Comprehensive Sewerage Plan Combining Projects 2, 4, and 5

The plan as now proposed calls for laying a conduit about 10 ft. 9 in. in diameter, starting on the south side of the Charles River Basin at the junction of the new South Charles conduit and the diversion from the Ward Street pumping station, thence extending across the basin about 950 ft. to the Cambridge connection and about 10,450 ft. along the north side of the basin under Harvard and Longfellow bridges and across the lower end of the

basin again to the south side to the connection for overflows from the Boston marginal conduit. At this point provision will be made to divert continuously from the conduit to the new works the low "foul flow," as well as to take the storm overflows at high tide. A few hundred feet farther on, an emergency pumping station will be located at the top of the shaft intake to a deep rock tunnel. At this point the design includes, in addition to the pumps, the purpose of which is described below, a grit removal and screening plant for the removal of heavy solids before entrance into the tunnel. From this point a 10-ft. diameter tunnel will extend 13,600 ft. to join the North Metropolitan at Chelsea Creek at the bottom of the shaft located north of the creek, where similar grit removing, comminuting, and screening works will be installed to remove heavy solids from the North Metropolitan discharge into the shaft. From this junction point gravity flow will continue by tunnel 12 ft. in diameter and 23,000 ft. long to an uptake shaft at Deer Island, at the site of the future treatment works. However, the sewage must be lifted about 50 ft. at this point to meet the grade of such future treatment plant and must in any event, even before such treatment, be similarly lifted to discharge into the existing outfall supplemented by an additional outfall of even greater capacity. Also, the sewage already discharged through the old North Metropolitan sewer at Deer Island must continue to be pumped to corresponding grades.

Under this comprehensive plan all low flows—that is, those occurring about 90 per cent of the time—will be discharged by gravity from the North Metropolitan relief sewer and the South Charles and North Charles conduits all the way to Deer Island, where all the pumping will be done. Under conditions of heavy storm overflows—that is, in about the wetter 10 per cent of the time—the over-all capacity for gravity flow will remain constant and little by little will be exceeded, requiring more and more use of the emergency pumping station at the Charles River Dam. This will continue until the total designed capacity of the combined works is reached, at

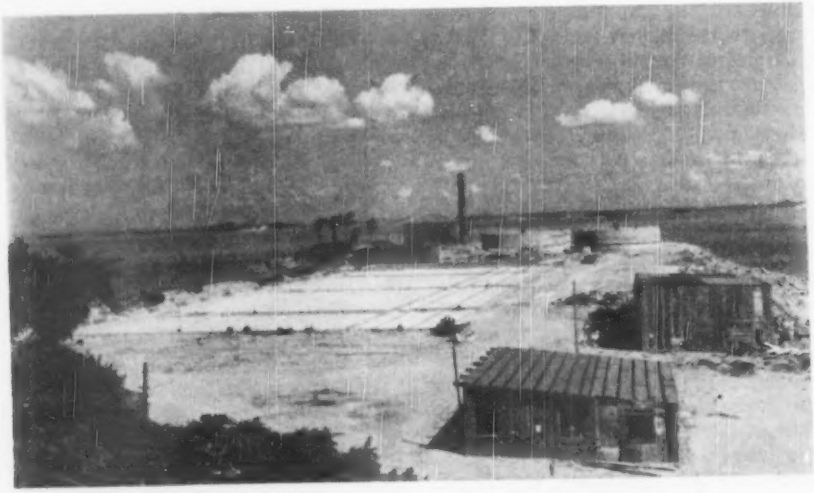


FIGURE 1.—General view of Nut Island sewage treatment plant.

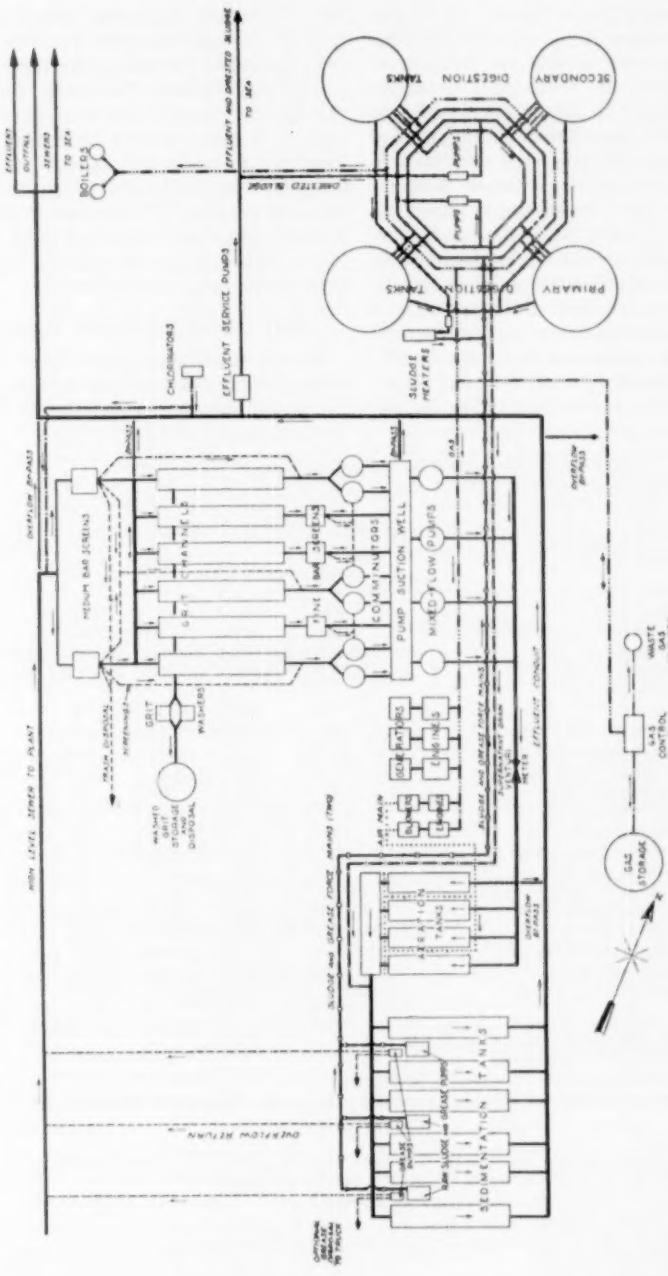


FIGURE 2.—Flow diagram of Nut Island sewage treatment plant.

which time (only a fraction of a per cent of the total time) there will be no flow from the South to the North Metropolitan, as the entire capacity of the tunnel to Deer Island will be needed for the North Metropolitan relief; and the entire South Metropolitan relief will be pumped to tidewater at the emergency pumping station at Charles River Dam. Under this comprehensive plan, no additional maximum capacity has to be provided in the works constructed under Project 2, North Metropolitan, but this capacity is taken advantage of by the South Metropolitan under all ordinary conditions of the lower flows. The maximum flows are based on the dilution factors recommended by the consulting engineers, including the factor of 3 for discharge into the inner end of the harbor, except that both for reasons of economy and to maintain sufficiently high velocities in the tunnels a smaller total quantity is carried all the way through to Deer Island and a greater quantity discharged into the inner harbor below the Charles River Dam under peak flow conditions.

Nut Island Treatment Plant

The sewage treatment plant now under construction at Nut Island (see Figure 1) has many interesting fea-

TABLE I.—Design Data for Nut Island Sewage Treatment Plant

Design Factor	Normal Dry Summer Weather		Present Average (1949)	Design Rate (1955)	Design Maximum
	1945	1955			
Sewage flow (m.g.d.)	70	90	95	112	300[1]
Occasional hourly minimum (m.g.d.)	45	60	—	—	—
Population served	700,000	900,000	700,000	900,000	900,000
Suspended solids[2] (lb./day)	140,000	180,000	140,000	180,000	180,000
Grit channels:[3]					
Number	2	3	3	3	6
Velocity, minimum (ft./sec.)	0.85	0.79	0.82	0.88	—
Velocity, maximum (ft./sec.)	0.95	0.86	0.89	0.98	1.04
Rate per comminutor[4] (m.g.d.)	17.5	15	15.8	18.7	25
Fine racks in operation[4]	0	0	0	0	3[5]
Pump lift, minimum (ft.)	7.6	8.1	8.2	8.4	—
Pump lift, maximum (ft.)	8.9	9.4	9.4	9.5	11.3
Aeration channel detention[6] (min.)	32	25	24	20	7.5
Sedimentation approach vel. (ft./sec.)	1.25	1.6	1.7	2.0	5.4
Sedimentation, detention[7] (min.)	141	110	105	88	33
Susp. solids removed (lb./day)	91,000[8]	108,000[8]	81,000[8]	90,000[8]	—
Raw sludge[9] (g.p.d)	215,000	255,000	191,000	213,000	—
Solids in dig. sludge[10] (lb./day)	57,000	67,500	51,000	56,500	—
Digested sludge[11] (g.p.d.)	84,000	100,000	75,000	82,500	—
Gas production[12] (cu. ft./day)	525,000	675,000	525,000	675,000	—

[1] Could be 350 under extreme conditions.
[2] At 0.2 lb. per day per capita.
[3] Six provided, each 10.5 ft. wide and 80 ft. long.
[4] Six 36-in. comminutors, 2 following each of 3 channels; fine racks following remaining 3 channels.
[5] At 50 m.g.d.
[6] Four parallel channels 166 ft. long, plus 85-ft. channel across ends; all in operation.
[7] Six covered tanks, 185 ft. by 68 ft. by 13 ft.; all in operation.
[8] Estimated at 65, 60, 58, and 50 per cent, respectively.
[9] Estimated at 95 per cent moisture.
[10] Estimated at 60 to 65 per cent of solids removed by sedimentation.
[11] At 92 per cent moisture.
[12] At 0.75 cu. ft. per capita per day.

tures (see Figure 2). It is designed to remove floating solids and grease; to reduce the amount of suspended solids to the extent possible in sedimentation tanks providing about 1½ hr. detention at the design rate, with the aid of 20-min. preaeration or flocculation with air; to prevent bacterial pollution of harbor and shore waters by chlorination of the effluent during the recreational season; to digest the sludge and discharge the innocuous residue through an outfall pipe to deep tidewater, or optionally to unwater and recover a small portion of the residue as low-grade fertilizing mulch; and to utilize the gas from digestion to furnish power for plant needs, including the necessary low-lift pumps and the aeration blowers. The principal features involved in the design are summarized in Table I.

Racks, Grit Channels, and Comminutors

The so-called medium racks, placed at the intake to the plant following the emergency spillway, have a clear opening of 1½ in. between rods. These racks are sufficiently rugged to eliminate the necessity of any prior coarse rack and yet are capable of removing rags that might interfere with the grit collecting mechanism immediately following. The mechanical racks are of the Manhattan grit-chamber type, with rake teeth protruding from the underside and with the rods supported and spaced by the rakes themselves. All the material collected on these medium racks is sorted by hand to remove large objects not capable of comminution. The remainder is then sluiced directly to the comminutors through by-passes around the grit channels. Material from each of the two racks can be sluiced to either one of two of the pairs of comminutors following some of the grit channels. The fine racks following the other grit channels are used only at very high flows or during comminutor repairs. Each of the fine racks is also equipped for the optional sluicing of rakings to one of two adjoining pairs of comminutors.

This arrangement of comminutors and fine racks in parallel is based on the fact that a comminutor is capable of handling a greater quantity of solids than is ordinarily fed to it in the normal sewage flow, and appears to be a most practical and effective type of grinder. Sewage effluent will be used for the sluicing of materials from both medium and fine racks through trash sluices to the comminutors. For this purpose a constant flow of sewage effluent is provided by pumping from the effluent conduit.

The grit is removed by scrapers of conventional design and elevated to a cross conveyor at the upstream end. The conveyor feeds two grit washers, from which the washed grit is elevated to an overhead hopper for loading into trucks.

Low-Lift Pumps

Four 48-in. pumps are provided, with a rated capacity of 83 m.g.d. at 10.3-ft. head; one normally acts as a spare. They are of the mixed-flow type with vertical shaft and bottom suction. On the top of each pump are mounted planetary reduction gears with built-in magnetic coupling and a 200-hp., 1,200-r.p.m., 2,300-v., synchronous motor, making a vertical self-contained pumping unit. The magnetic drive is capable of reducing the speed of the pump to 60 per cent of normal, with electric rectifier furnishing direct current for excitation. Each motor will be started manually at reduced voltage. Variations in the pump speed will be obtained manually from 0 to 100 per cent load and automatically from 60 to 100 per cent load by means of two potentiometers. The first will be operated by hand and the second by a float in the pump well. The motor will be brought up to speed manually and then transferred, if desired, to automatic control. This con-

trol maintains the level of sewage in the pump well at a constant elevation within a range of 3 in. above and below the normal level. There are no valves on the suction of the pumps, but stop-log provisions are made so that any pump unit can be isolated for major repairs. The only valve on the discharge of each pump is a lightweight flap gate of special design, protected by compression springs so that it can close on a large stick or other projection without damaging the gate hinge. Each of these gates can be isolated for repairs by stop-log provisions.

Venturi Meter

The influent conduit from the pumps to the preaeration channels contains a 120 × 60-in. Venturi meter with inlet and throat piezometer side connections of special design to prevent clogging with grease or sludge.

Aeration Tanks

At the point where the influent conduit discharges into the four parallel aeration channels the influent and effluent conduits are parallel, with a common dividing wall. A spillway is provided in this wall so that at or near the 300-m.g.d. capacity rate any possible surge due to lack of coordination of operation between pumps and tank gates will be damped out. The aeration diffusers are of the standard swing type with porous tubes. The entire normal low flow can be discharged through the two most northerly aeration channels; and two lightweight sluice gates are installed in the influent conduit to cut off what in that case would otherwise be a dead end. Control of the flow into and out of the aeration channels is over short-span low-head spillway bays only 30 in. wide closed by light, easily handled shutters. To compensate for the loss of head through the two sluice gates in the influent conduit the two northerly channels have only three such bays, whereas the two southerly channels have four. Also, the two northerly bays have a double deck of such spillway openings for use in case it is desired to confine high flows entirely to these two channels.

Sedimentation Tanks

From the aeration tanks the influent conduit extends along the west end of the six sedimentation tanks, with a common dividing wall containing two intakes to each tank, and having a reduction of cross section following each intake for maintenance of the velocity. Each intake is designed to take sewage from both the top (grease and scum) and bottom (sludge) of the influent conduit through orifices successively increased in size, in such manner as to get a satisfactorily mixed drawoff and an even distribution of solids to each tank. There are eight points of discharge through each tank wall, four from each intake, and small sluice gates at the intakes can shut off any tank from service. Grease and scum are prevented from collecting in the intakes behind these gates by being bled directly into the tanks over skimming weirs. Because of their nearness to many residences on high land adjacent to and overlooking the site the sedimentation tanks are covered.

The settling tanks are of standard rectangular flow-through type, with standard effluent troughs with V-notch crests, and standard sludge and scum-scraper mechanisms, except for a novel feature in the final collection of the scum. There are three grease and scum pumping stations at the head end of the sedimentation tanks, each station receiving the scrapings and skimmings from two adjoining tanks. The novel feature is contained in the method of returning the scum to these stations at the head of the tanks. The standard scum cross-collectors of every second tank are extended across the intervening space between tanks so that all the scum from two tanks is

brought into one, where it is picked up by an additional skimming mechanism operating along the side of the tank and separated by a baffle plate so close to the concrete side wall that the blades of the conveyor are only 10 in. wide. In this way the return of the scum to the head end of the tank (a distance of 143 ft.) is accomplished at the tank gradient, temperature, etc., to the pumping station.

The grease and scum spills over a manually controlled weir into a hopper supplying one of three pump suction lines, the other two being supplied from the hoppers into which the sludge is scraped from the two adjoining tanks. The grease hopper is $10 \times 7\frac{1}{2} \times 11$ ft. deep, the clearer liquid from the bottom being continuously decanted back into the adjoining main trunk sewer approaching the plant. There is ample head available for this purpose and the decanted flow is continuously available for sluicing back for a second circuit through the plant any material in the scum, or elsewhere, that may have gotten by the first time.

Sludge and Grease Pumps and Force Main

The pumps discharge sludge, or grease, or both, to the digestion tanks. There is a further provision by which the pumps can discharge grease to a tank truck if it is desired to sell the grease. The discharge to the digestion tanks may be through either of two 6-in. force mains.

These two lines are connected in such a way that they can form a continuous circuit for one-way travel of a mechanical apparatus for routine periodic cleaning. By suitable operation of valves, the cleaning apparatus can be stored in a by-pass off the line and again put into use without dismantling the line. Its position in traveling around the circuit will be mechanically recorded at the operator's desk in the main building, the mechanism for this recording being actuated by magnetic devices placed at intervals along the pipe.

Digestion Tanks

The sludge will be pumped to four 110-ft. diameter digestion tanks with 32-ft. sidewalls. Two tanks have fixed covers and two have floating covers with a 14-ft. maximum operating range. The bottom of each tank is divided into four cones. Each tank has a full working capacity of about 307,000 cu. ft., or 2,300,000 gal. The sidewall depth of sludge is 30 ft. The fixed cover tanks will be used as primary tanks and provided with recirculating facilities.

Dual-Fuel Power Plant

The power plant consists of one 850-b.hp., 750-kv.a. gas engine-driven generator unit; two 820-b.hp., 750-kv.a. dual-fuel engine-driven generator units; two 213-b.hp. dual-fuel engines, direct connected to 5,000-c.f.m. positive displacement-type blowers; and all necessary auxiliary equipment. The gas engine will operate solely on digester gas. The dual-fuel engines will run on digester gas and/or oil in any proportions from 95 per cent gas and 5 per cent oil to 100 per cent oil. There will be no outside electric service connection, all power and light required for the operation of the entire treatment works being generated in the power plant. With the exception of the blowers, which will be driven by direct-connected engines, all machinery will be driven by electric motors.

There will be no outside gas connection, any deficiency in gas being compensated for by the use of fuel oil in the dual-fuel engines and/or in the firing of the boilers. The gas-engine generator unit will be capable of carrying the entire electrical load for better than 90 per cent of the time, and it is estimated that gas production at practically all times will be in excess of that required to operate that unit. The two dual-fuel generator units will

be available for use at the higher loads and during periods of deficiency in gas. Together they will be able to operate the entire plant up to the design maximum sewage flow of 300 m.g.d. during the starting-up period when there will be no gas available. Similarly, with both blowers driven by dual-fuel engines, air up to 10,000 c.f.m. will be available at all times regardless of the gas supply.

Heating

It is proposed to maintain the contents of the digestion tanks at a temperature of about 90° F. This will be accomplished by circulating the hot jacket water from the engines through heat exchangers. The jacket-water digester heating system will be a closed system, operated continuously, in which the same water will be circulated by four 270-g.p.m. pumps, one of which will be a spare. The water will pass serially through the engine water jackets and through the heat exchangers for the digesters and thence to the pumps. Between the pumps and the engine it will be additionally cooled or heated to maintain the necessary balance between heat added and heat subtracted.

Provision will be made for the recovery of some of the heat in the exhaust gases from the gas engine for use in maintaining this balance in the winter time. The exhaust heater will be inoperative in summer. In addition to the exhaust gas heater, a steam heater will be provided to add heat as required to the jacket water between the pumps and the engines. The necessary coolers will have a capacity for removing all the heat added to the jacket water by engine operation. In other words, the engines can operate when no water is circulating through the heat exchangers for the digesters. The amount of heat supplied to the digesters will be controlled by varying the rate of water circulation in the heat exchangers, for which purpose valves will be supplied in the digester control house. Water pumped but not circulated in the heat exchangers will be returned automatically to the pumps through an overflow pipe, thus insuring circulation through the engines at all times.

Digested Sludge Outfall

To dispose of the digested sludge, a 12-in. submarine pipe was laid, in 1947 and 1948, about 2½ mi. northerly to the shore of Long Island at a point where provision has been made for receiving a similar digested-sludge branch outfall from treatment works to be constructed for the Boston Main Drainage Works at the Calf Pasture station. From that point the outfall continues about 1½ mi. along the shore of Long Island, and another ¼ mi. to water about 25 ft. or more deep on the south side of President Roads, across the channel from the existing Deer Island outlet of the North Metropolitan System. A continuous flow of sewage effluent at a velocity of about 2 ft. per sec. will be maintained in this outfall by a battery of three centrifugal pumps, normally connected in parallel but arranged to permit connecting in series for any emergency condition. The sludge will be added by positive displacement pumps. The discharge of digested sludge can be confined to outgoing tides. A mechanical apparatus for routine periodic cleaning will be provided to prevent the walls becoming coated to any marked degree with grease or other deposits. Built-in devices at Nut Island, at the Long Island junction with the future Calf Pasture line, and at the extreme northerly end of Long Island will provide means for inserting and removing the cleaning apparatus. The apparatus can optionally be forced all the way through to the submerged outlet. This outlet is designed to allow the apparatus to pass out in the clear, also to disperse the discharge through a channel 10 ft. long cast in a heavy concrete terminal block.

Effluent Outfall Diffusers

A novel feature of the new plant involves the placing of diffusers over the outer ends of the two 60-in. outfall pipes through which the effluent from the sedimentation tanks is normally discharged. First, each concrete dome 16 ft. 4 in. in diameter was precast, supported by 6 hollow steel-plate columns with bottoms shaped to fit the contours as determined by the diver. This dome was then lowered into position by threading over long steel rods previously set in holes drilled in the original paving around the upturned outlet. Then the diver placed 84 precast concrete beams 8¼ in. square and 12 ft. long extending radially from the rim of the dome. Concrete was then tremied into the column supports and up over the inner ends of the radial beams. As a result, the discharge is diffused to the outer edge of a grid about 36 ft. in diameter through 84 wedge-shaped openings with an aggregate area about 130 times that of the outfall itself.

The end of the westerly outfall was 24 ft. and the easterly outfall 30 ft. below mean low tide. The tops of the dome caps are now 4½ ft. higher and the average grid areas are about 25 and 31 ft., respectively, below low tide. Even under present conditions, temporarily discharging raw sewage, they are very effective in breaking up solids. After solids, and particularly the grease, are removed upon the completion of the proposed plant, a considerable improvement is expected as far as the sleek is concerned. The design permits a dragging anchor to ride over the top, doing little or no damage.

Reconstruction of Old Rack House

The present plans call for rebuilding the existing rack house into a new two-story building to match the other buildings in general appearance. This building will house on the first floor the existing boilers, the existing operating mechanisms for the gates at the head of the effluent outfall pipes, the superintendent's office, chlorine storage rooms, and first-aid rooms. It will house on the second floor laboratories, offices, service rooms, and a storage room. It is proposed to tear down the roof and walls of the existing rack house, to leave the major portion of the foundations, boiler settings, boilers, and chimney stack intact, and to build the new building of approximately the same area as the existing rack house.

Personnel

Prior to July 1, 1947, the work was done by the Metropolitan District Water Supply Commission, which was organized in 1926 to design and construct major extensions of the work of the Metropolitan Water District. That Commission had completed about $67,000,000 worth of water supply construction, and had been given by the Legislature the job of designing and constructing the five sewage works projects. On July 1, 1947, the Commission was abolished and a permanent Construction Division of the older Metropolitan District Commission was created to take over the water supply and sewage works construction work, and also to a large extent the personnel. The Commission consists of Commissioner W. T. Morrissey and Associate Commissioners M. Ulin, J. J. Grigalus, H. E. Stevens, and E. McPartlin. Under the direction of the writer as Chief Engineer of the Construction Division are Deputy Chief Engineer S. M. Dore, Designing Engineer L. M. Gentleman in the headquarters office, and Head Construction Engineer F. W. Gow in the field office.

Upon completion of construction, each project will be turned over for operation and maintenance to the Metropolitan District Commission's Sewerage Division, of which T. A. Berrigan is Director and Chief Engineer.

THE OXYGEN REQUIREMENTS OF ACTIVATED SLUDGE DETERMINED BY MANOMETRIC METHODS

II. Chemical Factors Affecting Oxygen Uptake

By P. S. S. Dawson and S. H. Jenkins

Research Assistant and Chief Chemist, Birmingham, Tame and Rea District Drainage Board, England

In Part I (*Sewage Works Journal*, 21, 4, 643; July, 1949) the authors described the use of manometric methods for studying the oxygen uptake of activated sludge, particularly under different physical conditions. The present paper is concerned with the effect of a wide range of inorganic and organic chemicals on the oxygen uptake. These experiments are intended to be exploratory and to demonstrate the ease with which it is possible to ascertain the immediate effects of substances at various concentrations.

Because of the large number of substances tested, detailed studies could not be made of the effect of those of particular importance, such as industrial wastes. Furthermore, the information yielded so far only relates to the addition of shock doses of chemicals to an activated sludge unaccustomed to dealing with the substances. Work will be carried out in due course to find the respiratory activity of sludge that has previously received frequent doses of the substance under investigation.

Experimental Procedures

A fresh sample of washed activated sludge was used for each day's experiment. One ml. of a solution of the substance under test was added to the reaction flask of a Warburg manometer, followed, usually, by 4 ml. of activated sludge. The atmosphere in the flask was air and the uptake was determined at 28° C. Whenever possible, the flasks were duplicated. However, owing to limitations of apparatus, one or two determinations in a series of dilutions had to be carried out in a single manometer.

The effect of each substance was tested simultaneously on the same sludge over a wide range of concentration, usually from 1 part in 100 to 1 part in 100,000,000. The oxygen uptake was observed at frequent intervals during a period of 3 to 4 hr. It was clear from all the results that the effect of a shock dose of any of the substances added occurs very rapidly. A few results taken from a large number of experiments are shown (Figure 1) to illustrate this point. It will be seen that the depression in the oxygen uptake is rapid and that it persists for at least 2½ hr. Further illustrations of this point are given later.

Effect of Cations

The results obtained when some cations of industrial importance are added to activated sludge are shown in Figure 2. The results have been calculated to a sludge of uniform suspended solid content and adjusted so that each of the different sludges used has the same oxygen uptake. However, the concentration of cation shown represents the amount actually present in the activated sludge concentration employed. There were considerable

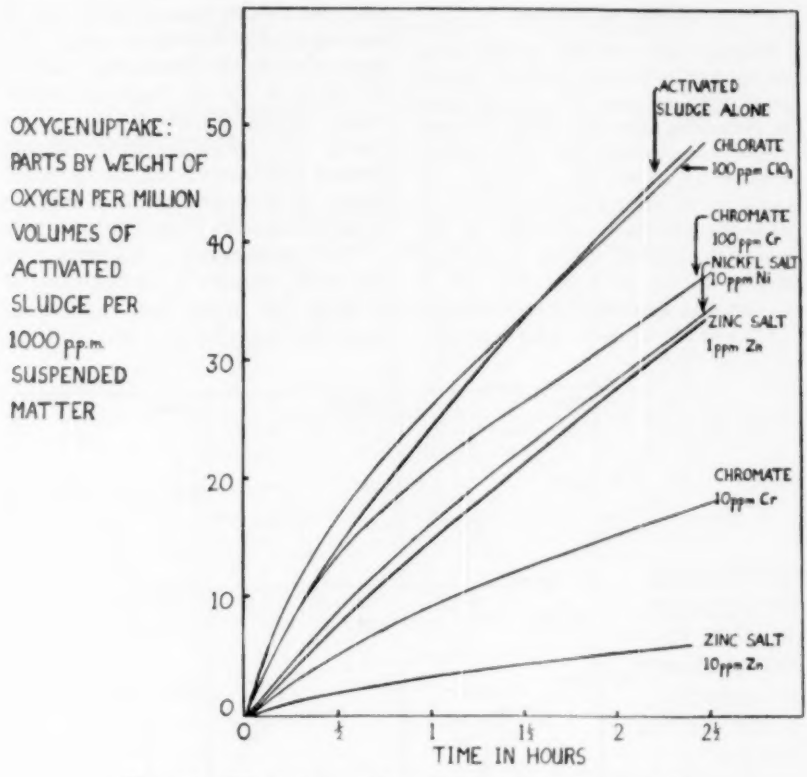


Figure 1.—Effect of several ions on the rate of oxygen uptake.

variations in the amount of suspended solid content of the activated sludge—that is, from about 3,500 to 7,000 p.p.m.—owing to the fact that spot samples were used before the results of analysis became available.

Striking features about the curves in Figure 2 are their characteristic sigmoid shape and the fact that so many cations appreciably depress the respiration at concentrations of about 100 p.p.m. It is worth emphasizing that these experiments are concerned entirely with oxygen uptake, without regard to such other effects as substances might produce on flocculation or deflocculation. Zinc appeared to be the most toxic cation, a depressing effect being observable at 1 p.p.m. Other work in progress has shown that sewage is capable of precipitating considerable amounts of zinc, besides other metals, from solution during sedimentation and that 1 p.p.m. of zinc added to sewage as a soluble salt would probably not reach the aeration plant in the soluble form.

In several cases, the oxygen uptake when traces of the metals were present was slightly greater than the uptake for the sludge alone. The experiments were not sufficiently replicated to decide whether this was due to a genuine stimulus caused by the trace of metallic ion, or to errors resulting from the small volume of sludge used.

Effect of Anions

Sodium salts of the purest compounds available were used for experiments with anions. In several cases the potassium salts were used, the same results being obtained. The results (Figure 3) show that a higher concentration of anions is required to depress the oxygen uptake than is the case with cations. With anions the oxygen uptake does not fall off so rapidly with increasing concentrations.

A point of interest with chromate was that a shock dose of 100 p.p.m. Cr was required to depress the oxygen uptake, whereas the continuous addition of 10 p.p.m. Cr (1) impaired nitrification and caused deterioration in the purity of trickling filter effluent. Quastel and Lees (2) found that 1,225 p.p.m. of potassium chlorate arrested nitrate formation from nitrite in soil.

With thiocyanate, a constituent of gas works effluents, a concentration of at least 100 p.p.m. was required to cause any appreciable reduction in the

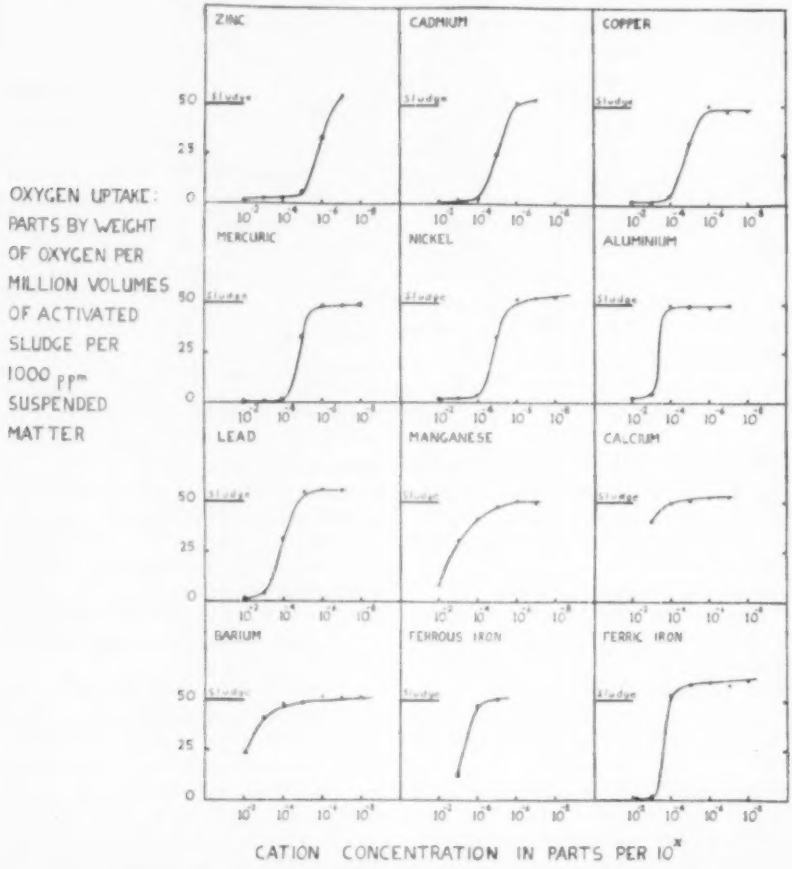


FIGURE 2.—Effect of cations on the oxygen uptake in 2½ hr.

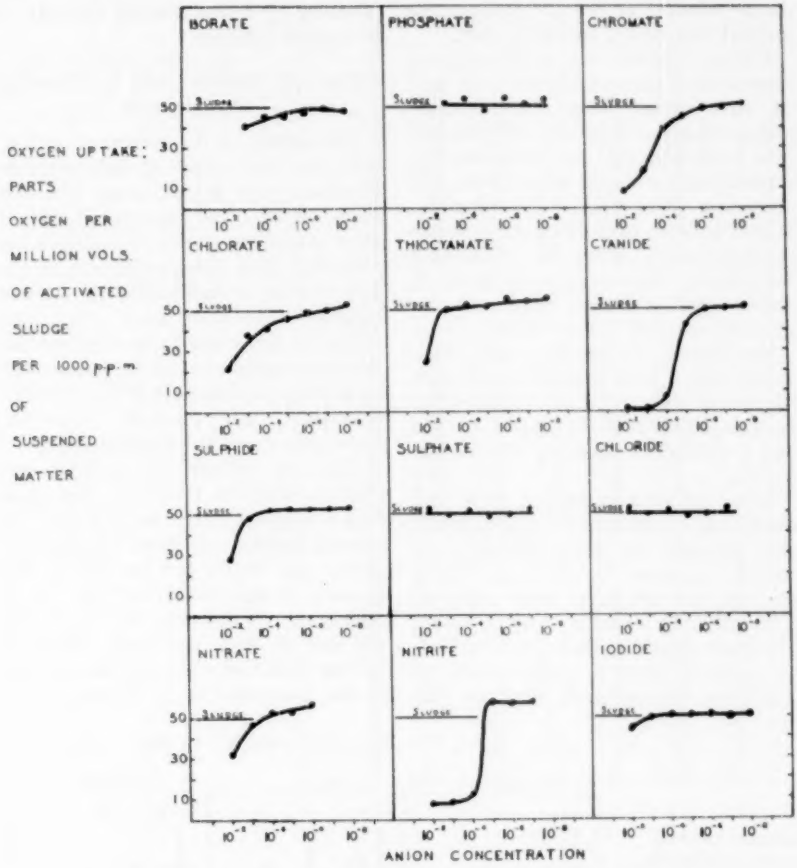


FIGURE 3.—Effect of anions on the oxygen uptake in 2½ hr.

rate of oxidation. Shock doses of 10,000 p.p.m. and 1,000 p.p.m. affected the oxygen uptake, but with higher dilutions the effects were negligible.

Nitrite had a marked depressing effect on respiration when the concentration was 100 p.p.m. N, but no effect at 10 p.p.m. The steep rise in oxygen uptake between these two concentrations suggests that there may be occasions when the presence of 10 p.p.m. N as nitrite is sufficient to reduce respiration, as indeed proved to be the case in a later experiment.

Effect of Mixtures of Ions

Experiments were set up to find out if ions that had previously been found to depress the oxygen uptake of activated sludge reinforced one another when present at the same time. Concentrations of ions were chosen which when present separately had reduced the oxygen uptake by about 25 to 50 per cent. In view of the many possible combinations of ions that might have been tried, the experiments were restricted to a sufficient number to in-

dicate whether or not the manometric method was useful for such work.

Figure 4 shows the oxygen uptake of activated sludge separately, as well as with copper, nickel, and cyanide alone and in combination; with manganese, cadmium, and zinc alone and in combination; and with copper, iron, and chromium alone and in combination. It will be seen that nickel and copper reinforce each other in depressing respiration, whereas cyanide added to either nickel or copper reduces the depressing effect of the cyanide.

Manganese, cadmium, and zinc, when paired, gave a greater reduction in uptake than either ion separately. In this experiment 10 p.p.m. of zinc had a negligible effect on the oxygen uptake.

With mixtures of copper, iron, and chromium, chromium did not appreciably increase the effect produced by copper, whereas the effects produced by iron and chromium were additive.

The limited number of experiments described indicates that the manometric method offers a quick means of predicting the probable effect on respiration of a complicated mixture of industrial effluents.

Effect of Metallic Ions in Chemical Combination

The effects on respiration of chromium, zinc, and copper in different combinations were found, using Warburg manometers. The results (Figure 5) show that a shock dose of chromate has less effect than chrome alum or chromium sulfate in depressing the oxygen uptake. The very small effect produced by chromium oxide suggests that the non-interference by chromium salts in sewage purification is due to their conversion into insoluble chromium hydroxide during sedimentation.

Zinc as sulfate or acetate was slightly toxic at 10 p.p.m. Zinc dust had a marked effect in reducing the oxygen uptake. Copper, as metal or oxide, was inert; but as sulfate and chloride it showed signs of toxicity at 10 p.p.m. In general, the conclusion reached is that the toxic effect of metals is exerted when they are present in the dissociated or ionic form.

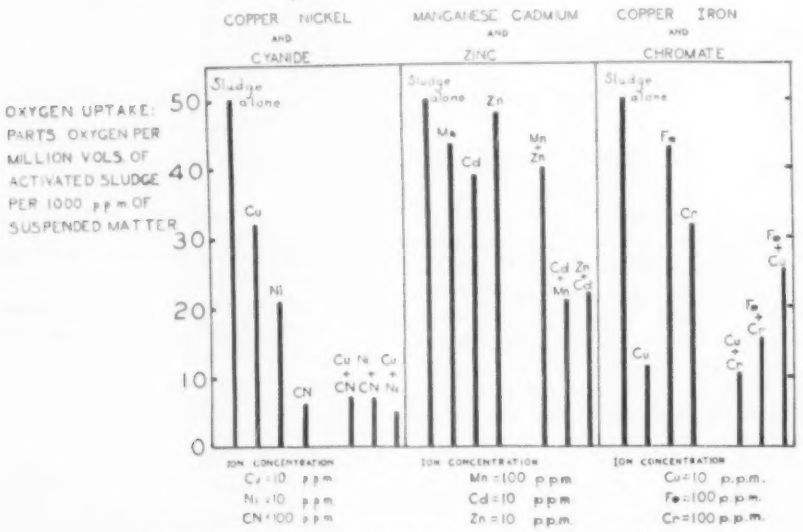


FIGURE 4.—Effect of mixed ions on the oxygen uptake.

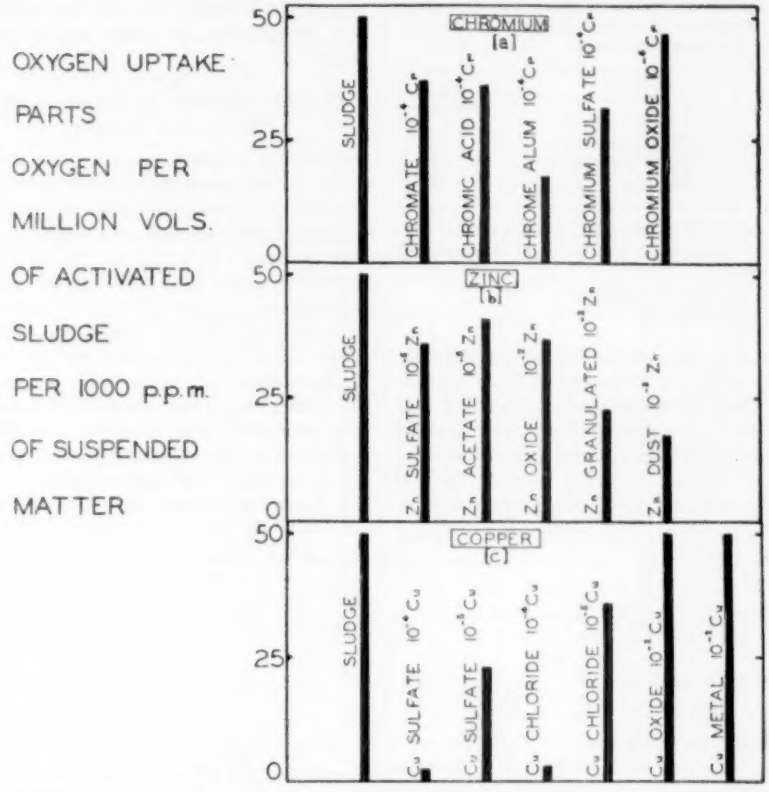


FIGURE 5.—Effect of metallic ions in different states of chemical combination.

Rapidity of Toxic Action

To test the speed of action of ions on the oxygen uptake, 4-ml. portions of activated sludge were placed in a number of Warburg manometers and 1-ml. portions of the ionic solutions in the side bulb of the manometer. The oxygen uptake of the activated sludge alone was found over a period of 90 min. The 1 ml. of solution was then tipped into the activated sludge and the determination continued. The results (Figure 6) prove that any effect the added substance may have is produced almost at once.

Effect of Sulfur Compounds

The effect of adding sulfur compounds to activated sludge is shown in Figure 7. Sulfide, thiocyanate, and thiourea depress the oxygen uptake, but only at the high concentration of 10,000 p.p.m. In this experiment the chemical oxidation of sulfide and sulfite caused interference in determining the biological oxygen uptake. This was overcome by using manometers containing water and sulfite, or sulfide, and deducting the resulting oxygen uptake from that obtained when activated sludge was present. The plot of the sulfite results shows the total

TABLE I.—Uptake of Oxygen by Activated Sludge and Activated Sludge Plus Sulfide (Warburg Manometers, 2 Hr. at 28° C.)

Mixture	Oxygen Absorbed[1]
Activated sludge[2]	277
Activated sludge[2] plus 10,000 p.p.m. S[3]	696
Activated sludge[2] plus 1,000 p.p.m. S[3]	493
Activated sludge[2] plus 100 p.p.m. S[3]	344
Activated sludge[2] plus 10 p.p.m. S[3]	290

[1] Parts by weight per million volumes of activated sludge containing 5,510 p.p.m. suspended solids.
[2] 5,510 p.p.m. suspended solids.
[3] As sodium sulfide.

oxygen uptake, including oxygen for the chemical oxidation of the sulfite.

Table I gives the results for the total oxygen uptake of activated sludge plus sulfide in various concentrations. The increased oxygen uptake in the presence of sulfide would suggest that this might become a serious competitor for oxygen in an activated sludge plant.

Oxygen Uptake in Presence of Nitrite and Nitrate

Mixtures of nitrite and nitrate were added to activated sludge and the oxygen uptake determined simultaneously using the same sample of sludge. The results after 1, 3, and 5 hr. (Figure 8) show that under the conditions of these experiments 10 p.p.m. of N as nitrite depressed the oxygen uptake, the maximum effect being produced by 50 p.p.m. nitrite N. After 3-hr. aeration the depressing effect of nitrite became less, and still less after 5 hr. The activated sludge used frequently produced a small amount of nitrate in the large-scale plant at the time of

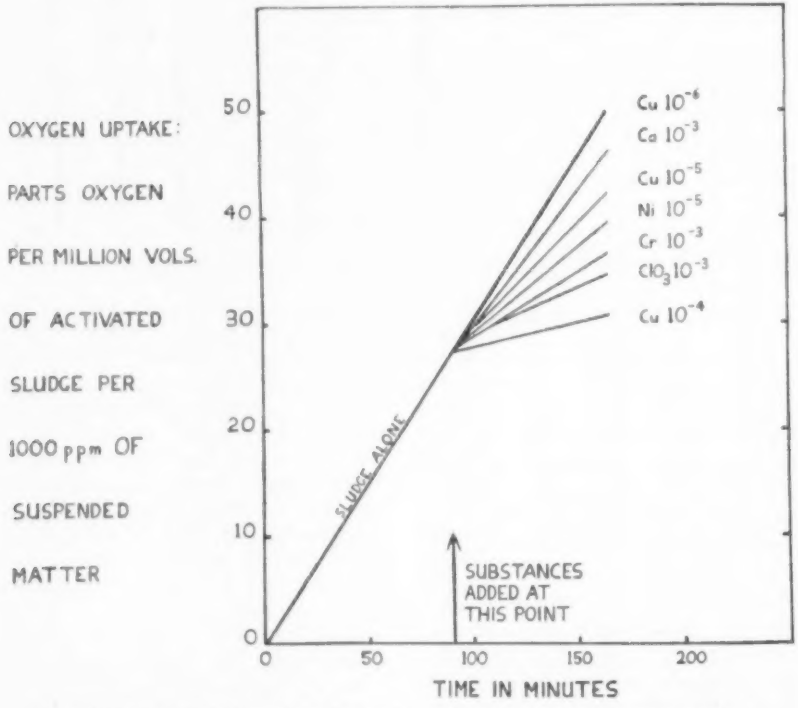


FIGURE 6.—Rapidity of the toxic action of various ions on oxygen uptake.

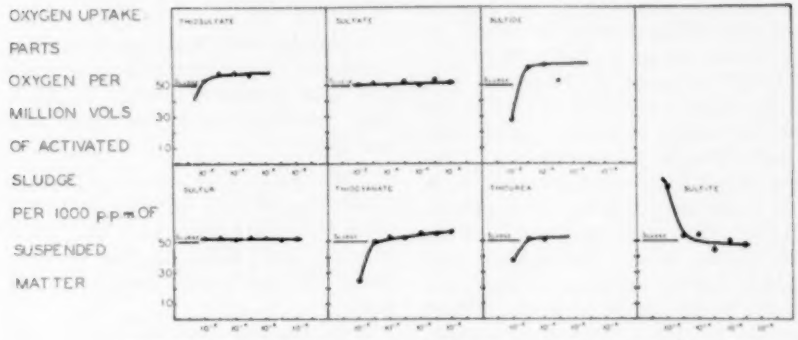


FIGURE 7.—Effect of sulfur compounds on oxygen uptake.

these experiments, and more when the conditions favored nitrification. It is, therefore, probable that with continued aeration the sludge became able to oxidize sufficient nitrite to reduce the nitrite concentration and so lessen its toxic action. This is supported by the fact that at the end of 5 hr. nitrite had disappeared from the flasks containing the two lowest concentrations of nitrite.

Effect of Organic Chemicals

Numerous investigators have determined the effect of adding organic chemicals of industrial importance to activated sludge. In most cases the chief concern has been to find out how much substance could be added to the sludge without interfering with its ability to purify sewage or to settle properly. The object of the present experiments was to use the manometric technic in order to survey the short-term effect of as many substances as possible applied once to fresh samples of normal activated sludge.

The possibility of interference being caused by the volatilization or atmospheric oxidation of the substance under test was prevented by employing the following schedule with each substance:

1. Duplicate sludge controls.
2. Sludge and substance both in the reaction flask.
3. Sludge in the reaction flask and substance in the side bulb.
4. Water in the reaction flask and substance in the side bulb.

Procedure 2 was duplicated whenever possible. This arrangement gave results in triplicate when four manometers were used, and permitted the effect of the substance to be determined on sludge undergoing oxidation.

Alcohols

It was found that 1 ml. of methanol, ethanol, or amyl alcohol almost completely and immediately suppressed the oxygen uptake of activated sludge. Ethanol, in 1-ml. portions diluted to give concentrations of 20, 10, 2, and

TABLE II.—Effect of Diluted Ethanol on Activated Sludge Respiration

Period	Oxygen Uptake (p.p.m.)				
	Sludge[1] Alone	Sludge[1] and Ethanol[2]			
		20%	10%	2%	0.2%
First 45 min.	55	83	106	161	63
First 90 min.[3]	108	84	119	268	131
Second 45 min.[4]	53	1	13	107	68

[1] Containing 3,920 p.p.m. suspended solids.
[2] Sludge in flask, ethanol in side bulb; concentration is ethanol in mixture after addition to sludge.
[3] Alcohol added to sludge at 46th minute.
[4] Increase in uptake after addition of ethanol.

0.2 per cent, when tipped into 4 ml. of activated sludge, had the effect on respiration shown in Table II.

It will be seen that the oxygen used in the flasks containing ethanol in the side bulb (that is, before tipping) was greater than in the control flask. This was proved, in other experiments, to be due to the oxidation by the sludge of ethanol which had vaporised from the side bulb. When the ethanol was tipped, further oxidation was stopped by the 20 per cent mixture and almost stopped by the 10 per cent mixture. The 2 per cent ethanol greatly increased the oxygen uptake, whereas the effect of the 0.2 per cent mixture was slight.

Organic Acids

Solutions were made up containing 1 per cent of the organic acid, neutralized with sodium hydroxide to pH 7. The following conditions were observed:

1. To 2.5 ml. of activated sludge, plus 0.5 ml. of Sorensen's buffer (KH_2PO_4/KOH, pH 7.4), 1 ml. of acid solution was added in the reaction flask, giving a concentration of 2,500 p.p.m.

2. In the side bulb 2.5 ml. of acid solution was placed to allow the acid to be added during the respiration of the sludge. The results obtained with some organic acids, calculated for a

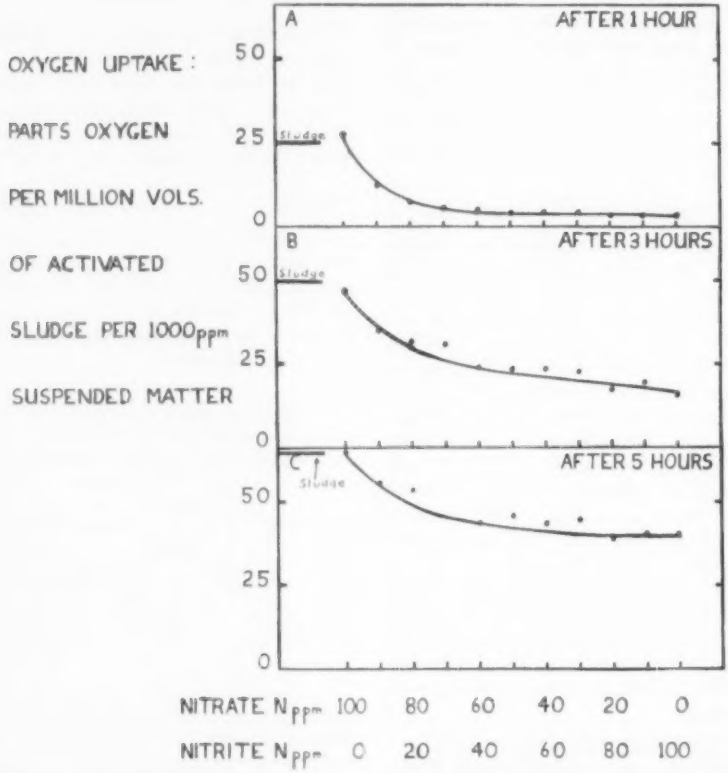


FIGURE 8.—Oxygen uptake in presence of various concentrations of nitrite and nitrate.

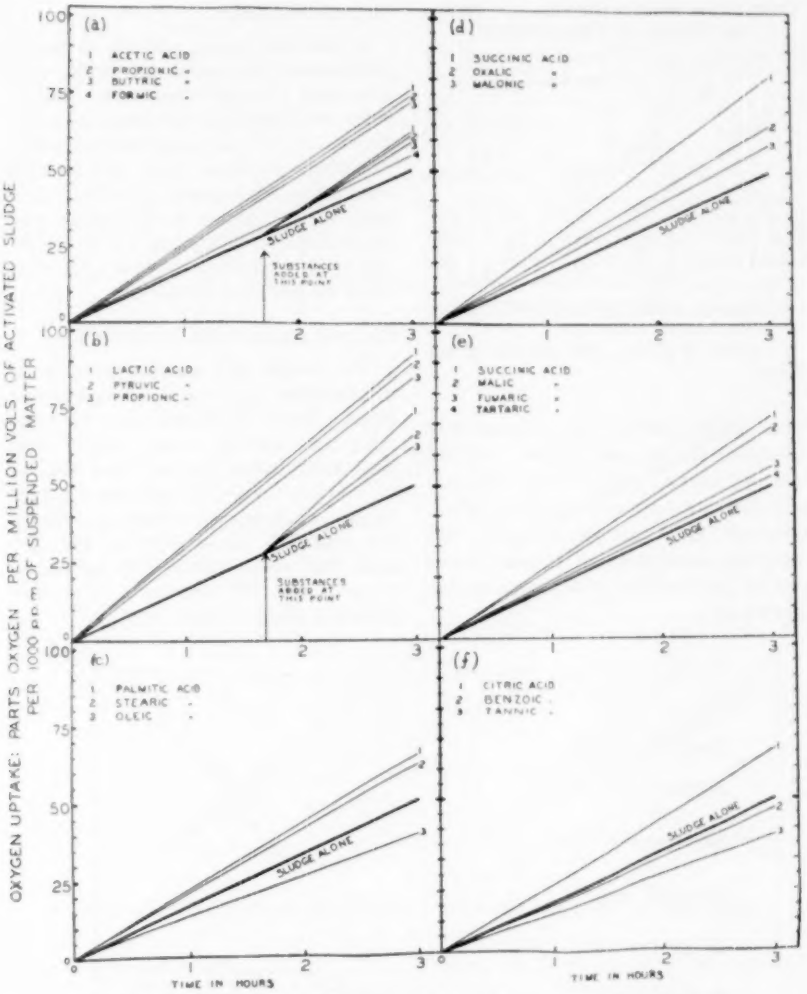


FIGURE 9.—Effect of sodium salts of organic acids on oxygen uptake (see text for concentrations).

sludge of uniform suspended solid content and for an acid concentration of N/120, are shown in Figure 9.

Acetate, propionate, and butyrate caused a marked and similar increase in the oxygen uptake. The rate of increase was the same when these substances were added some time after the sludge had been undergoing oxidation alone. Formate had relatively little effect in increasing the oxygen uptake. Lactate, pyruvate, and propionate showed increased uptakes of the same order (Figure 9b). Palmitate and stearate (Figure 9c) also gave an increase, whereas oleic acid depressed the oxygen uptake. Succinate gave an increase comparable with acetate; to a

TABLE III.—Effect of Methylamine, Aniline, and Pyridine on Oxygen Uptake

Period	Oxygen Uptake (p.p.m.)			
	Sludge[1] Alone	Sludge[1] Plus		
		Methylamine	Aniline	Pyridine
First 1½ hr.	82	81	83	82
First 3 hr.[2]	159	163	167	149
Second 1½ hr.[3]	77	82	84	67

[1] Containing 3,720 p.p.m. suspended solids.
[2] Substance added after 1½ hr.
[3] Increase in uptake after addition of substance.

lesser extent, oxalate and malonate also increased the oxygen uptake. Of the hydroxy dibasic acids tested, fumarate and tartrate had only a slight effect. Benzoate and tannate (Figure 9f) were the only salts of organic acids that had an inhibitory action on sludge respiration.

Organic Solvents

It was not found possible to obtain satisfactory replication of results with a number of organic solvents. The results were regarded, therefore, as qualitative. In 20 per cent concentration, naphtha, petroleum ether, and acetone completely suppressed oxidation; kerosene, toluol, carbon tetrachloride, and ether lowered oxidation by 50 to 90 per cent; and ethyl acetate effected a 10 to 50 per cent reduction.

Organic Nitrogenous Compounds

The results of a systematic study of nitrogenous compounds are described later. Table III shows that methylamine and aniline, when tipped into activiated sludge that had been absorbing oxygen for 1½ hr., produced a negligible effect on the oxygen uptake in the next 1½ hr. in spite of the fact that the concentration of substance present was 25 per cent. Pyridine caused a slight reduction.

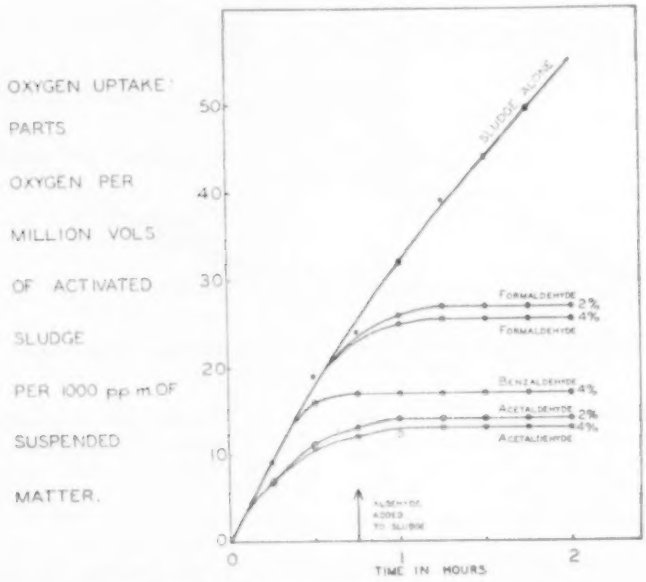


FIGURE 10.—Effect of aldehydes on oxygen uptake.

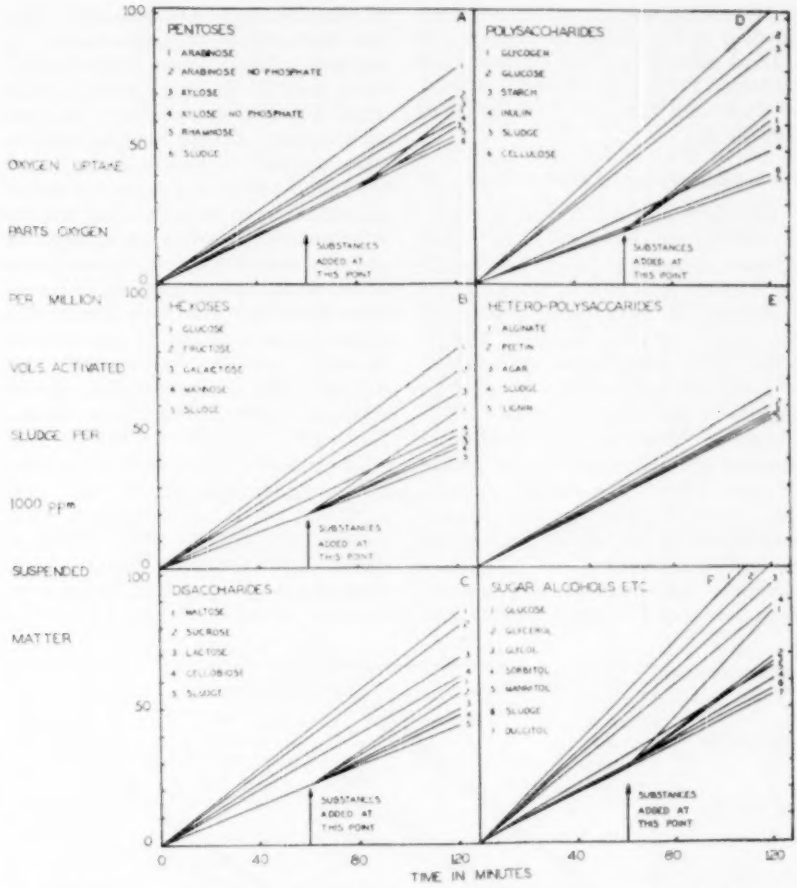


FIGURE 11.—Effect of carbohydrates and their derivatives on oxygen uptake.

Organic Toxicants

A few bactericidal substances were tested at different concentration in Warburg manometers. Phenol, cresylic acid, and urethane gave results resembling those produced by toxic inorganic materials. Aldehydes arrested the uptake of oxygen, exerting a toxic effect even before they were transferred from the side bulb to the sludge (Figure 10). This was due to the volatilization of the aldehyde and its absorption by the sludge.

Effect of Biochemically Important Compounds

This section deals with the effect on the oxygen uptake of activated sludge of carbohydrates, fats, steroids, amino acids, nitrogen bases, and micro-nutrients such as vitamins. Usually, 1 ml. of a 5 per cent solution or suspension of the substance under test was added at the beginning of the test to 2.5 ml. of sludge plus 0.5 ml. of buffer solution at pH 7.4.

In another manometer, the solution

or suspension was not added until respiration of the sludge had begun. In a third manometer, the reaction flask contained the 2.5 ml. of sludge, 0.5 ml. of water and 1 ml. of the solution or suspension.

Carbohydrates and Their Derivatives

Both arabinose and xylose increased the oxygen uptake (Figure 11a). The increase was greater in the presence of the buffer, probably because of the phosphate it contained. Rhamnose was practically without effect. The results showed a lag before the addition of arabinose and xylose produced an increase in the oxygen uptake.

Glucose, fructose, galactose, and mannose stimulated the oxygen uptake (Figure 11b). The oxygen uptake rose almost immediately these sugars were added to the sludge during the respiration experiment.

Maltose and sucrose both caused large increases in oxygen uptake and of the same order (Figure 11c). Lactose and cellobiose gave similar increases. These four disaccharides were oxidized from the moment they were added to the sludge. The ease with which certain polysaccharides were oxidized is shown by reference to Figure 11d. Glycogen caused a greater oxygen uptake than glucose when added from the start, but the position was reversed when they were added to the sludge undergoing oxidation alone for the first hour. The oxygen uptake caused by the addition of starch was also considerable. On the other hand, inulin had a smaller effect and cellulose no effect on respiration within a period of 2 hr.

The mixed polysaccharides alginate, pectin, agar, and lignin were only slowly or not at all oxidized by activated sludge (Figure 11e). Glycerol, glycol, and sorbitol (Figure 11f), when mixed with activated sludge from the start or added during the experi-

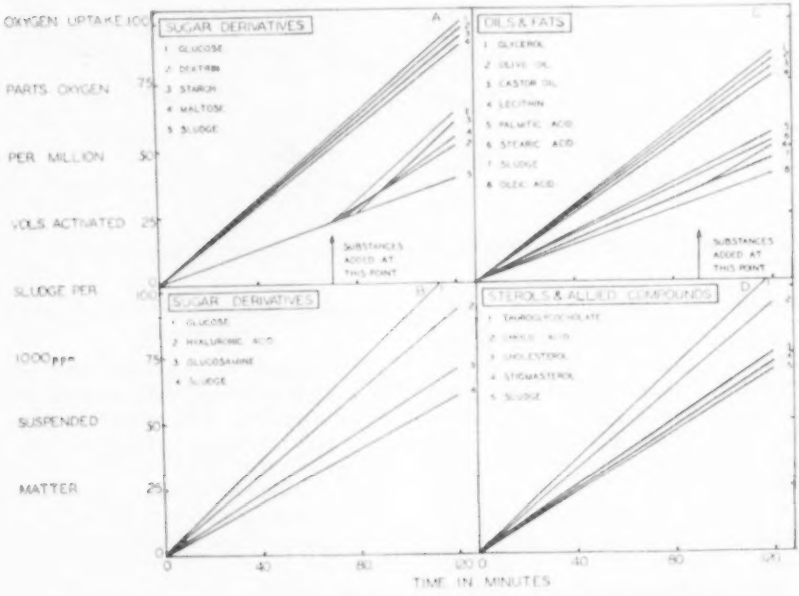


FIGURE 12.—Effect of sugar derivatives, fats, and sterols on oxygen uptake.

ment, approximately doubled the rate at which oxygen was taken up by sludge, although the increase was not as great as with glucose. Mannitol had relatively little effect; dulcitol, none.

Starch, dextrin, maltose, and glucose showed much the same oxygen uptakes (Figure 12a). This indicates that the rate of hydrolysis of the glucose derivatives is not a factor of importance limiting the rate of oxidation.

A representative uronic acid (hyaluronic acid) and an amino sugar (glucosamine) were found to be oxidizable by activated sludge (Figure 12b), although glucosamine caused only a slightly increased oxygen uptake. Both were less oxidizable than glucose.

Fats, Bile Acids, and Sterols

Fats containing fatty acids were tested and the results compared with those previously obtained with glycerol and fatty acids. The results (Figure 12e) suggest that the oxygen uptake of fats is due to the oxidation of the glycerol component, as the higher fatty acids are hardly oxidized in the first 2 hr.

Sodium tauroglycocholate, cholic acid, cholesterol, and stigmasterol were tested in 1 per cent solution. The sterols had little effect on the oxygen uptake. The increase observed with cholic acid and the tauroglycocholate (Figure 12d) is large, considering that

TABLE IV.—Effect of Amino Acids on Oxygen Uptake

Results expressed as parts of oxygen used in 2 hr. per million volumes of activated sludge containing 2,000 p.p.m. of suspended solids. The sludge alone used 143 parts of oxygen in 2 hr.

Amino Acid			Molecular Weight	Amino Nitrogen (%)	Increase in Oxygen Uptake (p.p.m.)		Increase in Oxygen Uptake (%)[2]	
No.	Type	Name			1% Amino Acid Sol.	Amino Acid Sol.[1]	1% Amino Acid Sol.	M/100 Amino Acid Sol.
1	Basic	Arginine	174	24.1	33	56	23	40
2		Histidine	155	18.1	26	41	18	28
3		Lysine	132	21.2	33	43	23	30
4		Tyrosine	181	7.7	78	140	54	98
5	Aromatic	Phenylalanine	165	8.5	39	65	28	45
6		Tryptophane	204	13.7	46	90	32	66
7	Pyrrolidine	Proline	115	12.2	110	127	77	88
8		Hydroxy proline	131	10.7	46	60	32	42
9	Aliphatic	Glycine	75	18.6	93	69	65	48
10		Alanine	90	15.5	43	39	30	27
11		Valine	117	12.0	57	67	40	47
12		Leucine	131	10.7	122	159	85	112
13		Isoleucine	131	10.7	51	67	36	47
14	Sulfur	Methionine	149	9.4	103	153	72	107
15		Cystine	240	11.7	74	178	52	125
16	Hydroxy	Serine	105	13.3	114	120	80	84
17		Threonine	119	11.8	80	95	56	66
18	Acidic	Aspartic acid	133	10.5	102	136	72	95
19		Glutamic acid	145	9.6	83	119	58	84

[1] Calculated as M/100.

[2] Expressed as percentage of oxygen demand of the sludge.

these bile acids are used to suppress the growth of non-intestinal organisms in the isolation of intestinal organisms.

Amino Acids

Using thrice-washed activated sludge, the groups of amino acids referred to in Table IV were tested by the methods already described at a buffered pH of 7.4. The activated sludge used contained approximately 2,000 p.p.m. of suspended solids. Straightline relationships were obtained with the 19 amino acids used, and all resulted in an increase in oxygen uptake. With 5 exceptions, there was a lag of 10 to 30 min. following the addition of amino acid before an increase in oxygen uptake occurred. The results are given in Table IV.

The addition of all the amino acids increased the oxygen uptake of the sludge, the uptake increasing least with those containing the most amino nitrogen (Figure 13). The period of aeration was too short for nitrification to account for the additional oxygen uptake, which was probably due either to the supply of an available form of nitrogen or to the supply of oxidizable carbon.

Peptones and Proteins

One per cent solutions of peptones from casein and silk, bacteriological peptone, and a peptone from yeast were examined in triplicate. The proteins used, in 1 per cent solution, were egg albumen, a glutelin, a casein, and gelatin. The results (Figures 14a and 14b) show that the peptones greatly increased the oxygen uptake and that this effect was produced without a time lag. The proteins caused a smaller increase than the peptones and there was a marked time lag before the effect was shown.

Nitrogen Bases

The following purines and pyrimidine derivatives were tested in 1 per cent solution at pH 7: adenine, guanine, xanthine, allantoin, alloxan, uric acid, and uracil. Alloxan depressed the oxygen uptake slightly after 1 hr. and 2 hr., but the other substances were without effect.

Betaine, choline, skatole and guanidine in 1 per cent solution at pH 7 varied greatly in their effect on sludge respiration. Betaine and choline had no action, whereas skatole and guanidine inhibited respiration (Figure 14e). The results with guanidine at different concentrations (Figure 14f) show that the critical concentration lies between 100 and 1,000 p.p.m.

One per cent solutions or suspensions of urea, creatinine, and hippuric acid gave the results shown in Figure 14d, in which the effects of urea and uric acid are included. With the exception

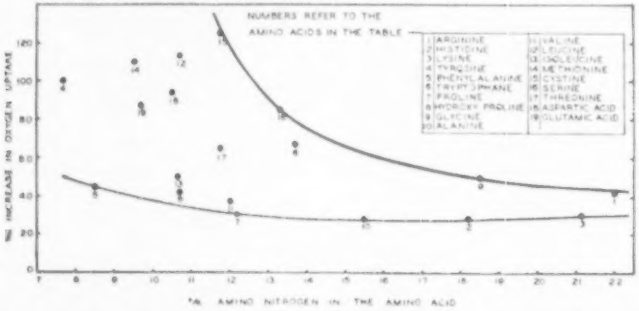


FIGURE 13.—Relationship between percentage of amino nitrogen in added amino acids and the increase in oxygen uptake.

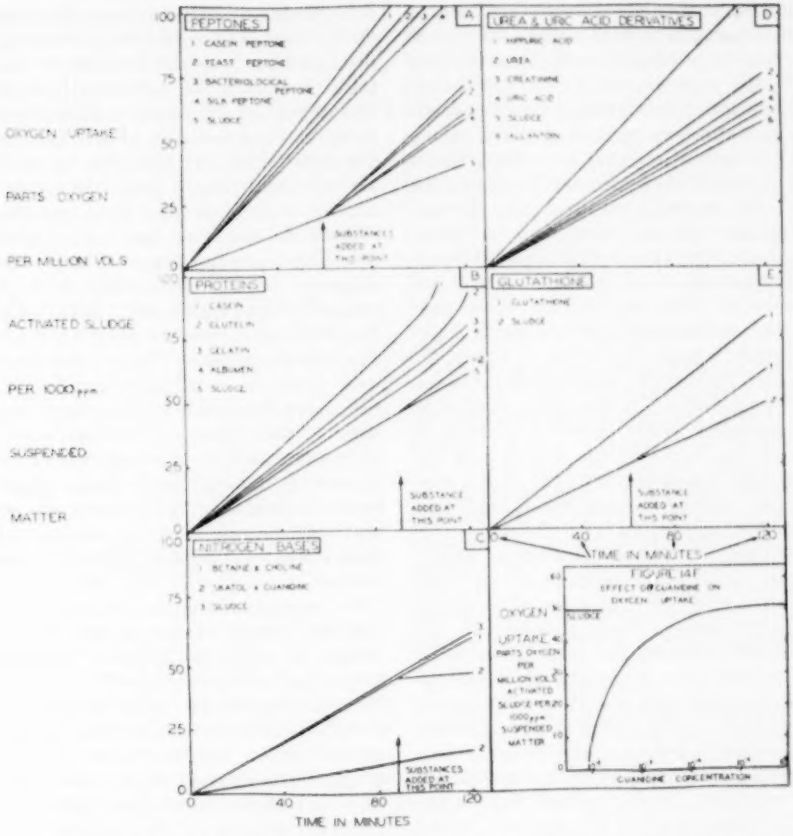


FIGURE 14.—Effect of various nitrogenous compounds on oxygen uptake.

of hippuric acid the effects were only slight.

Growth Factors and Micronutrients

Over a range of concentrations from 10 to 10,000 p.p.m. the following substances were selected for test purposes: nicotinic acid, ascorbic acid, thiamine, inositol, and p-amino benzoic acid. No change in the oxygen uptake of the sludge resulted. Glutathione in 1 per cent solution and at pH 6.8 gave an increase (Figure 14e), somewhat less in amount than that for peptones.

Discussion and Summary

1. Using manometric methods, the effect of shock doses of a wide variety of chemicals on the oxygen uptake of activated sludge has been investigated. The experiments were of short duration. An attempt has not yet been made to use this method of approach for the study of activated sludge that has received a succession of doses of a particular substance, such as would occur in a treatment plant dealing with an industrial effluent.

2. In Part I of this paper it was

shown that when a minimum rate of shaking had been reached, additional shaking produced no further increase in the oxygen uptake rate. This supports the view expressed by other workers that once a minimum concentration of dissolved oxygen is reached in an aeration tank, no further benefit in the rate of oxidation is obtained by increasing the oxygen concentration. However, oxygen dissolved in a mixed liquor at the end of an aeration tank is not wasted. The experiments show that even when activated sludge is thoroughly washed it still has a steady demand for oxygen and that the demand is proportional to the concentration of suspended solids present; in fact, at any one moment, the demand of the sludge is greater than that of the sewage. During the separation and concentration of the activated sludge, oxygen will be used by the sludge. Otherwise, anaerobic conditions will quickly ensue, with consequent loss of condition by the sludge. One symptom of this loss of condition has been shown to be a reduction in the rate at which oxygen is absorbed when aerobic conditions are restored. This reduction is of short duration following anaerobic conditions lasting for periods of up to a few hours. Permanent injury occurs only after prolonged absence of oxygen. These changes in the sludge conditions were related to changes in electro-potential.

3. The importance of pH, temperature, and sludge concentration has already been referred to in Part I. The experiments on concentration suggest that the air supply in an activated sludge plant determines the maximum concentration of sludge that may be carried.

4. The metabolic activity of sludge has been studied on a broad basis. Many inorganic substances act as toxicants when single doses of 1 to 100 p.p.m. of the metallic ion are added. Generally, the effect is immediate and persistent, and is shown by a reduction in the rate of oxygen uptake. There is scope for the development of manometric methods for the study of effects produced by frequent addition of metallic toxicants to activated sludge. The probability is that in sewerage systems receiving metallic wastes, most of the metal, with the exception of chromate, is precipitated from the sewage during sedimentation. Zinc, copper, chromium, cadmium, and nickel were found to be among the most toxic substances. Sulfide and sulfite, at high concentrations, had such a large oxygen demand as to mask their toxic action on the sludge. Some toxic ions were found to be additive in their effect, others tended to neutralize the effect of one another. In cases where the probable action of a mixture of substances on an activated sludge plant has to be predicted, the experiments on toxicants indicate that the manometric technic has possibilities well worth exploring.

5. Organic substances, with a few exceptions, mostly increased the oxygen uptake of activated sludge. Glucose, starch, and compounds built up from the glucose molecule caused the greatest stimulus, the results suggesting that the oxygen uptake was limited by the rate of glucose oxidation rather than the rate at which the glucose molecules were set free by enzymic hydrolysis. According to the results, it seemed that the liberation of the glucose molecule was necessary to obtain the maximum oxygen uptake because some glucose derivatives were not oxidized as rapidly as glucose or starch. Some polysaccharides, such as cellulose, did not affect the oxygen uptake in the short period of experiment. It is probable that compounds of that kind become associated with the sludge and are in time resolved into simpler substances capable of undergoing oxidation.

The increase in oxygen uptake which pentoses, hexoses and disaccharides caused when added to activated sludge shows that activated sludge, because of its mixed flora, is well endowed with

the oxidative mechanisms necessary for the breakdown of a wide variety of compounds. The lipoids were also oxidized with ease. In this case, it is probable that the increased oxygen uptake was due to the glycerol fraction of the molecule, as the higher fatty acids were only slightly oxidized. The hemicelluloses were unaffected by activated sludge. Because the pentoses, which constitute an important part of the hemicelluloses, are oxidized by activated sludge, it is inferred that the absence of hydrolytic enzymes prevented the oxidation of these substances within the space of a few hours.

6. With nitrogenous compounds, the effects produced by amino acids were variable, although all were oxidizable. In general, the higher the nitrogen content, the lower was the increase in oxygen uptake. A time lag of 10 to 30 min. occurred with most of the amino acids used. Proteins gave a limited oxygen uptake, whereas peptones, their breakdown products, were oxidized without any time lag. It is clear that simple and combined amino acids are capable of being utilized by activated sludge for respiratory metabolism.

7. Micronutrients and growth factors were of no importance in the respiratory activity of activated sludge. The mixed flora in sludge and the nature of sewage make it unlikely that essential growth factors are missing.

8. A few experiments with nitrite and nitrate showed that nitrite could be toxic when present in sufficiently high concentration. However, the nitrite did tend to disappear and, it was presumed, was replaced by nitrate. The authors have not yet carried out any work on nitrification using micromanometers. It is probable that new microanalytical methods will be required before this is possible, or that the use of larger manometers will be necessary.

Acknowledgments

This work is published with the permission of F. C. Vokes, Engineer to the Birmingham, Tame and Rea District Drainage Board. The authors' thanks are due to Professor R. H. Hopkins, Professor M. Stacey, Dr. F. W. Norris, and Dr. P. W. Kent of Birmingham University, England, for providing some of the biochemical substances. The authors also wish to acknowledge the assistance they have received from several members of the laboratory staff.

References

1. Jenkins, S. H., and Hewitt, C. H., "The Effect of Chromate on the Purification of Sewage by Treatment in Bacterial Filters." *Journ. Soc. Chem. Ind.*, **54**, 41 (1940).
2. Quastel, J. H., and Lees, H., "Bacteriostatic Effects of Potassium Chlorate on Soil Nitrification." *Nature*, **155**, 276 (1945).

STUDY OF THE NITRIFICATION PHASE OF THE B.O.D. TEST *

By A. M. Buswell, Irene Van Meter, and J. R. Gerke

Illinois State Water Survey, Urbana, Ill.

Until recently, the idea of the existence of two distinct stages of oxidation in the B.O.D. reaction—that is, carbonaceous followed by nitrogenous oxidation—has been generally accepted. However, it has been recognized for some time that the interpretation of results of the 5-day B.O.D. test, particularly when applied to sewage plant effluents, has been complicated by the occurrence of nitrification before complete carbonaceous oxidation. This was pointed out by Mohlman (1) in 1938.

In an article published in 1948, Ruchhoft, *et al.* (2) noted the need for further study and revision of the theory of clear-cut two-stage oxidation. In an investigation of 45 samples (in customary sewage dilutions) conducted by Ruchhoft, Placak and Ettinger (3), one sample showed nitrite formation by the first day, four showed it by the fifth day, and 19 by the tenth day. They also show that when the B.O.D. values for one series are corrected for nitrification, the erratic curve obtained by plotting B.O.D. against incubation time becomes a smooth curve—

$$y = 2.823\ (1\text{–}10^{-0.135*T})$$

—agreeing well with the calculated carbonaceous B.O.D.

Various procedures for eliminating nitrification during the B.O.D. test have been suggested. Among these are the pasteurization followed by reseeding, and chlorination followed by reseeding, discussed by Sawyer and Bradney (4). Acidification, followed by neutralization and reseeding, as well as pasteurization and reseeding, has been studied by Hurwitz, *et al.* (5). The bacteriostatic effect of methylene blue as applied to nitrification has been investigated by Abbott (6) (7).

In all of these studies the oxidation of ammonia apparently occurred concurrently with the carbonaceous oxidation. It was thought that information as to the rate of ammonia oxidation in an inorganic medium in which ammonia is the only oxidizable substance would prove of interest and value. However, attempts along this line were hampered by the fact that excessively long lag periods were encountered. Instead of a lag period of hours, the nitrifying organisms under the conditions of these experiments have shown lag periods of days or weeks. For example, in one of the earlier series (No. 15), the B.O.D. after three weeks was only 0.6 p.p.m., but after five weeks the B.O.D. had reached 8 p.p.m., thus utilizing all the dissolved oxygen. The nitrite nitrogen formed was 2.6 p.p.m. Ruchhoft (3) notes the variability in the onset of nitrite formation, even in duplicate bottles of the same dilution. From a bacteriological viewpoint, it appears that an explanation of the long lag phase and the erratic appearance of nitritation (nitrite formation) in the B.O.D. test might lie in the size of the inoculum and an understanding of the generation time of the nitrifying organisms.

* This work was carried out under U. S. Public Health Service Research Grant 762–C to the Federation of Sewage Works Associations.

Growth Rate

Little specific information on growth rate of nitrifying organisms was found in the literature (8). A general statement on growth time has been found useful.

Generation time is that interval during which one cell develops and completely divides into two cells. Mathematically, it is expressed (9):

$$g = \frac{t}{3.3 \log b/B}$$

in which g is the generation time, t is the total time, b is the number of cells at the end of time t, and B is the number of cells at $t = 0$.

The generation time of microorganisms is dependent on the conditions of growth and the nature of the specific organisms. Heterotrophic organisms have a comparatively short generation time, as follows:

Generation Times of a Few Heterotrophic Organisms (9)

Organism	Generation Time (min.)
Proteus vulgaris	21.5
Escherichia coli	16.5 to 17
Aerobacter aerogenes	17.2 to 17.4
Eberthela typhosa	23.5
Diplococcus pneumoniae, type 1	20.5
Clostridium butyricum	51
Rhizobium trifolii	101 to 174
Rhizobium japonicum	343.8 to 460.8

On the other hand, the autotrophic organisms are noted for their long generation time. Considering that they must synthesize their entire protoplasm from carbon dioxide with energy released by the oxidation of inorganic compounds, it would be expected that the length of time required for the synthesis of a cell would be greater. Ellis (10) reported that under favorable conditions the generation time of *Beggiatoa* (an autotrophic sulfur bacterium) is 24 hr.

As the generation time of *Nitrosomonas* was not known quantitatively, it was determined as follows:

Each of three series was prepared by adding to 1 part of inoculum (taken from the immediately preceding series) 10 parts of fresh substrate, as follows:

Series	Length of Incubation	Nitrite N Formed (p.p.m.)
C	6 days	1.13
I	6 days	1.16
N	5 days	1.17

It can be seen that each succeeding series was inoculated with the same proportion of nitrifying cultures showing approximately the same activity. From this it can be assumed that the number of cells present, when the subculture reaches the same activity as the culture used as inoculum, is 11 times the original. Using these values, the generation time of our culture, under the conditions present, appears to be about 31 hr. Thus, in 31 hr., x nitriting cells become $2x$ cells in a B.O.D. bottle at 20° C., whereas in only 6 hr., x cells of heterotrophic *Escherichia coli* become $98x$ cells in milk at 37° C. (11).

Although the above figures are only approximations, they may explain how it could take 3 to 5 weeks for a substrate inoculated with relatively few cells to show enough oxidation of ammonia to be detected by chemical means.

Proceeding along this suggested line of attack, success has been attained in producing an inoculum that results in complete nitritation in 5 to 6 days with no significant lag phase. This was accomplished by means of a series of successive inoculations.

Study Results

The initial observance of nitritation in this group started with Series 15, which was one of a number of series in which the medium was varied in an attempt to shorten the lag phase. In this particular series, the $(NH_3)N$ was

increased to 19.3 p.p.m. Seeding was accomplished by the addition of 4 drops of well dispersed trickling filter effluent to each bottle. The seeding would amount to about 0.7 to 0.8 ml. per l. After 3 weeks, the B.O.D. was only 0.6 p.p.m., but after 5 weeks the B.O.D. had increased to 8.0 p.p.m. This is shown in Figure 1. Practically all of the dissolved oxygen had been utilized; 2.6 p.p.m. $(NO_2^-)N$ had been formed.

At this time there were in the incubator a number of bottles of Series 11. These originally had been seeded with 0.1 ml. per bottle of an inoculum prepared from soil in Winogradsky's medium (12). Successive tests over a period of two months had shown no evidence of nitritation. One of the bottles of Series 15 showing active nitritation was used on the 36th day of incubation to reinoculate Series 11, in the amount of 1 ml. per bottle. The size of the B.O.D. bottles is such that this amount of inoculum would be about 3.5 to 4 ml. per l. After a lag of about 6 days, the B.O.D. showed a progressive rise. Roughly one-third of the $(NH_3)N$ had been oxidized in two weeks. There were insufficient bottles for intermediate tests, but by the end of the third week, nitritation was apparently complete.

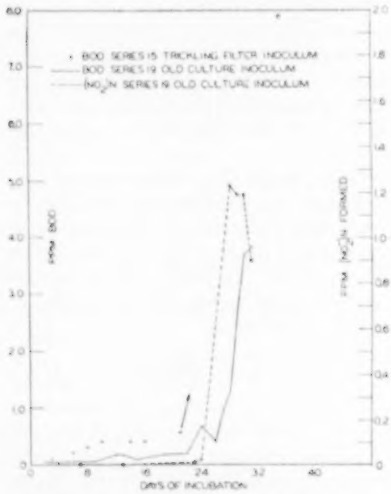

BOD SERIES 15 TRICKLING FILTER INOCULUM
BOD SERIES 19 OLD CULTURE INOCULUM
$(NO_2)N$ SERIES 19 OLD CULTURE INOCULUM
P.P.M. BOD
P.P.M. $(NO_2^-)N$ FORMED
DAYS OF INCUBATION

FIGURE 1.—Rates of nitritation with poor inocula.

Three weeks after completion of nitritation, or on the 42nd day after reinoculation of Series 11, it was used as seeding material for Series 19, in the amount of 4.5 ml. to 1 l. of dilution water. Figure 1 shows that the lag period was three weeks, or about three times as long as for reseeded Series 11. The action was complete in slightly more than four weeks. The amount of inoculum used was comparable to that used in the reseeding of Series 11. It might be significant to note that three weeks had elapsed after completion of nitritation in Series 11 before it was used to inoculate Series 19.

Series 19, on the 34th day of incubation, or at about the time of completion of nitritation, was then used as inoculum for Series 22. The amount added was 29.8 ml. per l. For this series, glass stoppered 500-ml. flasks were used to permit determination of D.O. $(NO_2^-)N$, and $(NH_3)N$, on the same sample. A sample was siphoned from the flask into a B.O.D. bottle and the D.O. determined in the usual way. The substrate remaining in the flask was then used for the determination of $(NO_2^-)N$ and $(NH_3)N$. The lag period was shortened to about 6 days and nitritation was complete in 10 to 14 days. Thus, Series 22 is similar to Series 11 in length of lag phase and in that both were seeded with organisms at a time of, or not long after, active nitritation. However, for Series 22 approximately 6.5 times as much inoculum was used. Also, Series 22 completed nitritation in a much shorter time.

The ammonia determinations for Series 22 in the dilute concentrations were hampered by analytical difficulties. The use of synthetic rubber stoppers in the stills caused contamination, which was not eliminated by the

customary treatment of boiling the stoppers in caustic soda. For this reason, all-glass stills were adopted. As only 50 ml. were available from the incubation flasks, the largest amount of ammonia nitrogen was 60 gammas. This required almost complete distillation of sample to reduce the percentage of error to a permissible figure.

In order not to lose the inoculum while working on the $(NH_3)N$ determination, it was planned to carry on inoculations into fresh media periodically, following the activity by means of the $(NO_2^-)N$ formed. The first such inoculation was series A, in which 100 ml. from a bottle of Series 22 were added to 1 l. of the usual substrate. The seeded mixture was then poured into B.O.D. bottles. The first test was made on the 9th day of incubation, at which time 1.13 p.p.m. $(NO_2^-)N$ had been formed. Thus, almost complete oxidation of the ammonia present had occurred. Series B was seeded from A, Series C from B, and so on through Series F. Table I summarizes the data for these series, as well as those for the preceding ones.

The quantity of inoculum in Series A, B, C, D, and E was the same in each case, but the series differed as to condition of inoculum at the time of use. Series C had formed as much $(NO_2^-)N$ in 6 days as A had in 8 days, yet when C was used for seeding, D the latter series was only slightly more than half as fast as C. This might have been due to the fact that the

TABLE I.—Nitritation Rates Resulting from Different Amounts of Inoculum in Different States of Activity

Series	Initial $(NH_3)N$ (p.p.m.)	Inoculum				Per Cent Nitritation	Time (days)	Remarks
		Amount (ml./l. of medium)[1]	Source	History				
				Age (days)	Condition			
15	19.3	0.7–0.8	Tr. filt. effl.	0	Fresh, well dispersed	—	—	3 to 4 wk. lag; O depleted by end of 5th wk.
Reseeded 11	1.5	3.5–4.0	Series 15	36	In active nitritation	100	15–21	6-day lag; incubated for 60 days prior to reseeding
19	1.14	4.5	Series 11	42	3 wk. after completion of nitritation	100	28	3-wk. lag
22	1.40	29.8	Series 19	34	6 days after completion of nitritation	100	10–14	6-day lag
A	1.2 ±0.1	100	Series 22	12	In active nitritation	94	9	Incubated in water bath
B	1.2 ±0.1	100	Series A	10	In active nitritation	100	8	Incubated in water bath
C	1.2 ±0.1	100	Series B	9	In active nitritation	94	6	Incubated in water bath
D	1.2 ±0.1	100	Series C	6	In active nitritation	50	6	Incubated in water bath[2]
E	1.2 ±0.1	100	Series D	6	Incomplete nitritation	12	8	Incubated in water bath[2]
F	1.2 ±0.1	100	Series E	8	Incomplete nitritation	9	10	Incubated at 20° C.

[1] Medium consisted of standard dilution water (*Standard Methods*, 9th Ed., p. 140) except $(NH_3)N$ was changed as indicated in table and 0.11 g. Na_2CO_3 per liter was added. pH was adjusted with HCl.

[2] Temperature 4° to 5° C. lower than for Series A, B, and C.

maximum and minimum temperature during incubation of D, and also E, was 4° to 5°C. lower than the maximum and minimum temperature during the previous series. These series were part of those incubated in a water bath and the building temperature was somewhat lower during the Christmas holidays while Series D and Series E were being incubated. Whatever the cause for the slowness in the rate of nitritation in Series D, it had produced appreciable $(NO_2^-)N$ when it was used for seeding E. The lag phase in Series E was prolonged for at least 8 days. It should be noted that the incubation temperature for E was comparable to that for D. Series F was seeded from Series E while E was still in the lag phase, and was incubated at 20° C. In the case of Series F, the lag phase extended for at least 10 days.

Additional Series

In view of the apparent effect of the stage of nitritation on the length of lag period and the rate of nitritation in the seeded substrate, it was decided to prepare a new group of series using Series A, B, C, D, and E, respectively, as inocula, as shown in Table II. In all of these, except E, essentially all of the $(NH_3)N$ had been oxidized when Series G, H, I, J, and K were prepared. These were incubated at 20° C.

Figure 2a shows a comparison of the five series. Series I, which was inoculated with C, showed very little lag, if any, and virtually complete nitritation by the 6th day. G exhibited a short lag period of about 4 days, but the action was complete by the 6th day. The other three showed somewhat longer lag periods, but all apparently had completed nitritation by the 10th to 14th day.

On the 14th day of incubation, 100 ml. per l. from each of Series G, H, I, J, and K were used for seeding as shown in Table II. Figure 2b shows that in all five of the new series nitritation proceeded rapidly with very little, if any, lag. In at least one bottle of each series complete nitritation was accomplished in 6 days. These results show that fairly consistent and rapid ammonia oxidation is obtained when the inoculum has just reached the peak of nitritation and is used in sufficient quantities. This would indicate that the variability of incidence of nitrite formation in the B.O.D. test is due in part to the long generation time and to the variability of the inoculated substrate with respect to the numbers and metabolic activity of nitrifying organisms.

Quantitative work on the growth rate of nitrifiers is now under way.

TABLE II.—Rate of Nitritation Using Inoculum at Height of Activity

Series	Inoculum[1]		Nitritation		
	From Series	Age (days)	$(NO_2^-)N$ Formed (p.p.m.)[2]	Days	Per Cent
G	A	43	1.17	6	97
H	B	33	1.17	8 to 14	97
I	C	24	1.16	6	97
J	D	18	1.17	10	97
K	E	12	1.25	14	100
L[3]	G	14	1.11	6	82
			1.29	6	97
M[3]	H	14	1.17	5	97
			1.15	6	96
			0.964	6	80
N[3]	I	14	1.17	5	97
			1.15	6	96
			1.16	6	97
O[3]	J	14	1.16	6	97
			1.15	6	96
P[3]	K	14	1.17	6	97
			1.16	6	97

[1] 100 ml. inoculum to 1 l. of dilution water. Medium contained 1.2 ± 0.1 p.p.m. $(NH_3)N$ as $(NH_4)_2SO_4$.

[2] Corrected for initial $(NO_2^-)N$, which ranged from 0.04 to 0.13 p.p.m.

[3] Duplicate bottles analyzed on the 6th day.

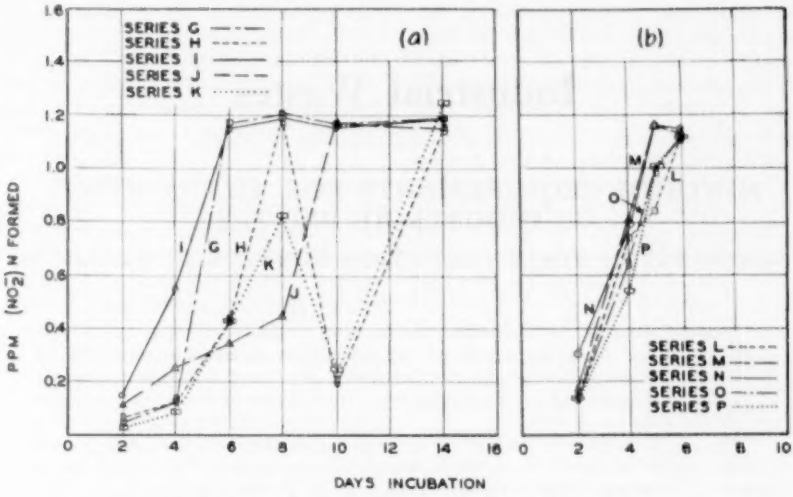


FIGURE 2.—Rates of nitritation with active inocula.

With the results of this study, it will be possible to attack the problem of separating the carbonaceous phase and the nitrification phase of the B.O.D. test, or to make better corrections for nitrification.

References

1. Mohlman, F. W., "Nitrification." THIS JOURNAL, **10**, 4, 792 (July, 1938).
2. Ruchhoft, C. C., Placak, O. R., Kachmar, J. F., and Calbert, C. E., "Variations in B.O.D. Velocity Constants on Sewage Dilutions." *Ind. and Eng. Chem.*, **40**, 7, 1290 (1948).
3. Ruchhoft, C. C., Placak, O. R., and Ettinger, M. B., "Correction of B.O.D. Velocity Constants for Nitrification." THIS JOURNAL, **20**, 5, 832 (Sept., 1948).
4. Sawyer, C. N., and Bradney, L., "Modernization of the B.O.D. Test for Determining the Efficacy of Sewage Treatment Processes." THIS JOURNAL, **18**, 6, 1113 (Nov., 1946).
5. Hurwitz, E., Barnett, G. R., Beaudoin, R. E., and Kramer, H. P., "Nitrification and B.O.D." THIS JOURNAL, **19**, 6, 995 (Nov., 1947).
6. Abbott, W. E., "The Bacteriostatic Effect of Methylene Blue on the B.O.D. Test." *Water and Sewage Works*, **95**, 424 (1948).
7. Abbott, W. E., "Suppression of Nitrification and Denitrification During the Determination of B.O.D. I." *J. Soc. Chem. Ind.* (England), **67**, 373, (1948). "II." *Ibid.*, 399.
8. Nelson, D. H., *Cent. f. Bakt*, II Abt., **83**, 287 (1931).
9. Porter, J. R., "Bacterial Chemistry and Physiology," pp. 121–129. Wiley & Sons, Inc. (1946).
10. Ellis, D., "Sulphur Bacteria," p. 94. Longmans & Green Co. (1932).
11. Frazier, W. C., and Whittier, E. O., "Studies on the Influence of Bacteria on the Oxidation-Reduction Potential of Milk. I. Influence of Pure Cultures of Milk Organisms." *J. Bact.*, **21**, 239 (1931).
12. Waksman, S. A., "Principles of Soil Microbiology," p. 66. Williams & Wilkins Co. (1927).

Industrial Wastes

MINIMUM REQUIREMENTS FOR THE CONTROL OF INDUSTRIAL WASTES

WASHINGTON STATE POLLUTION CONTROL COMMISSION

Although titled as "requirements," the practices outlined here are actually fundamental procedures for in-plant prevention and reduction of industrial waste discharges. The Washington State Pollution Control Commission is believed to be the first agency of its kind to establish such practices under its authority to develop rules and regulations for stream pollution control.

The requirements were drafted by a committee of the Water Pollution Control Council, Pacific Northwest Area, which includes representatives of pollution control agencies in Montana, Idaho, Oregon, Washington, the Province of British Columbia, and the Territory of Alaska. The Committee members were E. F. Eldridge, Director and Chief Engineer, Washington State Pollution Control Commission and Kenneth H. Spies, Chief, Water Pollution Control Section, Oregon State Sanitary Authority.—Ed.

Foreword

The Pollution Control Law of 1945 invested in the Pollution Control Commission the power to adopt, prescribe, and promulgate the rules, regulations, and standards necessary to carry out the purposes of the Act. It is the established policy of the Commission to employ judgment and reason in the enforcement of the provisions of this law and to apply cooperative measures in every case possible to obtain the necessary and desired results.

Pollution by wastes from industry exceeds by many times that resulting from domestic sewage. One of the reasons for this high pollution load is the lack of understanding on the part of certain industrial management of the effects of industrial pollution. Much of the load contributed by industry can be eliminated by careful operations and comparatively inexpensive waste prevention measures. Waste saving measures have been known to result in profit to certain industries. The true value of these measures, however, is in the reduction of the pollution load on public waters or on the operation load applied to municipal sewage treatment facilities in case the industry has access to the municipal system.

The minimum requirements listed below are designed to bring about more careful industrial operation and to promote waste prevention. To be of most value they must be, and are, applied on an industry-wide basis and as such will constitute a fair and reasonable means of reducing industrial pollution. It is expected that in some cases these measures will not be sufficient to solve a pollution problem and that further reduction by waste treatment will be necessary. However, waste treatment will not be required until waste prevention has been given a fair trial.

The staff of the Commission is available to discuss the various problems created by these regulations. Plans

for installations to be used to comply with them must be submitted to the Pollution Control Commission for approval before they are constructed. In this way the experience of the staff will be made use of in providing effective facilities.

Waste materials resulting from waste prevention measures as provided for by the minimum requirements below must be disposed of in such a manner as to insure that they will not, either directly or indirectly, enter any State waters.

The following definitions will apply to terms used herein:

Industrial wastes are the water-borne wastes resulting from industrial processes or from the development of a natural resource.

Waters of the State includes all rivers, streams, ponds, lakes, inland waters, underground waters, salt waters, and other surface waters and water courses within the jurisdiction of the State of Washington.

Minimum Requirements

Slaughterhouses and Meat Packing Plants

1. Yards and holding pens shall be dry cleaned before washing down.

2. Kill blood shall be separately collected and the blood thoroughly squeegeed from the floor into the collection tank. The disposal, or utilization, of the blood thus collected will depend on local facilities, but must be accomplished in a manner which conforms to sanitation regulations.

3. Paunch manure and hog stomach contents shall be collected separately and used as fertilizer, land-fill, or in any other satisfactory manner. A fine screen is recommended wherever its installation is feasible.

4. Fleshings, grease particles, and other solid material shall be collected by dry cleaning of floors and screening of wastes.

5. Adequate grease recovery basins shall be installed on drain lines from by-product processing rooms. These traps shall be skimmed and cleaned at least once each day. (Note: In the larger plants it is recommended that small basins be located wherever high-grade greases can be recovered in significant quantity and that a main basin be installed on the main drain line. Wastes not containing grease should be by-passed around the basin.)

Poultry Killing and Packing Plants

1. Provision shall be made for the collection of blood from the killing and bleeding and for the disposal of this blood in a satisfactory manner.

2. All manure, feathers, entrails, and other material removed from the carcass of the fowl shall be collected and the floor and equipment thoroughly dry cleaned before washing down. Provision shall be made for the proper disposal of this material.

Milk and Milk Products Plants

1. Whole milk, skim milk, buttermilk, whey, condensed milk products, dried milk products, or spoiled milk or milk products shall not be dumped or otherwise allowed to enter a drain line which leads, either directly or indirectly, to a State water.

2. Mechanical can washers, both straight-line or rotary, shall be equipped with a drip collector and the drip milk collected and disposed of in a manner which conforms to sanitation regulations.

3. Milk or milk products left in sanitary lines, tanks, and equipment before washing shall be drained into suitable containers and disposed of in a satisfactory manner as directed above. It is recommended that these lines and equipment be installed to slope slightly to the point of collection.

4. Leaks in pumps, pipe lines, and other equipment handling milk or milk products shall be repaired as rapidly as possible.

5. Accidental spillage shall be reduced to a minimum by providing appropriate alarms or automatic equipment to prevent such accidents and by proper instruction to personnel.

Canneries, Vegetable and Fruit

1. Vegetable and fruit canneries (unless other arrangements are made with this Commission) shall provide an efficient screen for the removal of skins, seeds, pomace, culls, discarded product, and other suspended material from the wastes from the washing, sorting, or other canning processes. This screen must be 40-mesh and may be of the vibrating, rotary, or any other effective type. It shall be located on the main outlet sewer line or lines from the cannery in such a way that all waste waters will pass through the screen except cooling condenser or other clean waters. The latter may be by-passed around the screen or discharged through a separate outlet. Prior to the installation of the screen a plan drawing of the facility shall be submitted to the Pollution Control Commission for approval, together with data as to capacity.

2. Screenings and other solid material removed from the product during the cannery operations shall be disposed of in a manner which will assure that it will not enter a State water.

Canneries, Fish and Shellfish

1. Discarded portions of fish and shellfish products which result from cleaning, sorting, and other cannery or fish product operations shall be collected and disposed of in a manner which will prevent these materials from entering a State water. (It is suggested that arrangements be made with rendering plants for collection of this material at regular intervals. This will necessitate the installation of a hopper or other suitable containers as well as screens over floor drains to retain the solids.)

Wineries

Wastes from dry wine production consist of pomace, lees, and wash waters. In addition, the manufacture of wine or brandy will produce still slops from the distillation process.

1. Pomace, which is a garbage-like material, shall not be allowed to enter the liquid waste waters. If disposed of on land, the location of the disposal field shall be such that seepage water from the pile will not enter a surface water and that flood waters will not carry the material into public waters. Prevention of ground-water contamination in the area must be also considered in the location of the field.

2. The major portion of the lees shall be separated and disposed of along with the pomace, unless arrangements are made by agreement with the Commission and the respective municipal officials for disposal in a municipal sewage system and treatment plant. If discharge to a municipal system is approved, facilities to spread the discharge over a period of time, rather than in batches, must be provided.

3. Still slops shall not be disposed of in the sewer system. This waste product disposal is a locality problem and is subject to the same requirements given for pomace if land disposal is used.

Breweries

1. Under no condition will brewer's grains be discharged to the sewer system. (Note: Grains have a definite market value and are almost always recovered and sold for cattle feed; however, provision must be made for holding or storage in case of breakdown or delay in transportation.)

2. Because of high concentration of grain liquor, grain should be sold in a wet condition. In case the grain is dehydrated, special arrangements must be made for the disposal of the liquor

by agreement with the Pollution Control Commission.

3. Spent hops shall be collected and disposed of as fertilizer, dumping on land, incineration or in some manner as to prevent this material from entering State waters.

4. Methods shall be devised for the separation and recovery of the yeast to prevent its entrance to the liquid waste drains.

Saw Mills, Veneer Mills, and Other Wood Handling

1. Sawmills and veneer plants located in close proximity to any waterway should take the following precautions in the disposal of waste sawdust, bark, slabs, and trimmings:

A. At the mill site, wastes should be kept out of any adjacent waterway and should be kept above the high-water mark and not in such a place that they will later be washed to the water. (Note: Underwater cutting is the cause of a considerable water pollution problem due to the formation of banks and piles of sawdust in the water. It is strongly urged that this practice be discontinued on an industry-wide basis, or that the area where the cutting is done be confined and the accumulated material disposed of on land.)

B. If debris is to be burned, a properly constructed burner is to be used and consideration given to the following:

(a) The burner should be well enough away from the water or other provisions be made, so that unburned wastes will not escape from the burner, either on the ground or through the air to the waterway.

(b) Chutes which cross a waterway when leading from the mill to the burner should be constructed in such a manner that wastes will not fall from the chute to the waterway.

(c) Burned-out screens and sections should be patched or replaced.

(d) Chutes carrying wastes to a burner under forced draft should be deflected downward or passed through a hopper or a series of baffles so that fine sawdust will tend to settle to the fire and not be carried out the screen.

C. Sawmills which truck sawdust and slabs away from a mill site should have these wastes dumped away from waterways, and in no case should sawdust and slabs be dumped below the high-water mark of the waterway or in such a position that they may be later washed or leached to the waterway.

2. When log ponds are located near water courses, the following precautions should be observed:

A. No log pond should be located in such a manner that the entire stream flows through the log pond.

B. The overflow should be regulated in such a way that the amount of sawdust, chips, and suspended materials that reach the waterway is reduced to a minimum.

C. Log ponds should be cleaned by dragging and dredging, rather than by flushing into a stream or river.

3. The sanitary and other provisions of the State and County Health Departments regarding logging and milling in watersheds above sources of drinking water supplies are to be carefully followed:

A. Permanent and semi-permanent camps should provide sanitary facilities, including

septic tanks and chlorination where necessary.

B. Septic tanks are to be cleaned by pumping and dry land disposal of sludge rather than flushing these tanks to the waterway.

C. Yarding logs across small streams should be carried out with due consideration to the damage caused to down-stream water users.

Oils and Like Material

1. "Oil" refers to the following: (a) Oils used for heating or power production; (b) oils used for lubrication; (c) oil emulsions used for cutting or cooling purposes; (d) petroleum cleaning fluids; (e) any other petroleum or asphaltic base compounds.

2. Ships, Cargo and Passenger—

A. Bilge or ballast water, waste, or other material containing oil in any amount whatever shall not be dumped or otherwise allowed to discharge from cargo or passenger ships into the waters of the State.

B. When loading oil, ship-to-wharf connections shall be such as to prevent leakage and the discharge of oil into the waters. Every precaution shall be taken to prevent accidental spills from either ship or shore facilities and to hold and recover such spills as may occur.

3. Oil Transportation Equipment—

A. Tankers, railroad tank cars, tank trucks, or other facilities used for the loading, unloading, and transportation of oil shall be equipped for the collection of the drip from hose or other connections and the excess oil contained in hose and pipe lines, wherever there is a possibility that this oil will find its way, either directly or indirectly, into a body of water. Provision shall be made, also, for catching accidental spills, and these facilities shall be of such a capacity as to hold the maximum quantity of oil possible from any one spill.

B. Roundhouses shall be provided for the collection of all oil and oil-and-water mixtures and an adequate separator shall be installed for the separation and recovery of both light and heavy oils from these mixtures. These separators shall be operated in such a manner as to assure their maximum efficiency.

4. Industry—Wherever practical, all waste oils and lubricants from industrial operations should be collected in containers for proper disposal. Oil emulsions used for machine cutting and tool cutting should be collected, treated, and reused wherever possible. In event that these emulsions are discarded, the emulsion must be broken down and the oil recovered for proper disposal. The general wastes from processes, if they contain oil, must be first passed through an adequate and well-operated oil separator before being discharged into the waters of the State.

5. Service Stations—Service stations with direct outlets to a body of water shall not discard oil to that water or so dispose of it in such a manner that it will be washed into the waters by run-off.

6. Municipal Sewers—Officials of cities, towns, and sewer districts are directly responsible for the control of oil discharged from their respective sewerage systems. It is strongly urged that ordinances be passed which will make it unlawful to dump or otherwise discharge oil into these sewer systems.

7. Disposal of Oil—Because it is usually desirable to dispose of waste or recovered oil by burning, this should be accomplished with due regard to local or other regulations and without

the production of nuisances or hazards. The location of disposal points shall be such as to eliminate any possible pollution of either surface or underground waters.

8. Immediate Action — Immediate steps shall be taken in case of an accidental spill to prevent the spread of the oil and to remove it from the water surface as completely as possible. (For large spills, booms of logs have been used to keep the oil from spreading. The oil may then be pumped from the water surface. Oil resulting from small spills and that remaining after pumping the larger spill can be removed by the use of old burlap, matting, or sawdust. These materials are then burned.)

9. Reports—In case of an accidental oil spill of an appreciable magnitude the party responsible shall make a full and complete written report within 3 days to the Pollution Control Commission. This report shall include the reasons for the accident and the provisions to be taken to prevent its recurrence.

Tanneries

1. A screen will be provided for the wastes from the beamhouse and all hair and fleshings will be removed and disposed of in a satisfactory manner. As a rule ⅛-in. round openings will be satisfactory for the screen for this purpose.

2. Lime sludge will be removed in as dry a manner as possible. If the lime is flushed out of the vats, ponds or settling tanks will be provided for the removal of the major portion of the lime from the wastes before it is discharged. In some cases, the water which collects above the lime sludge in the vats can be removed and the lime either shovelled or pumped to land or to ponds.

3. If the tannery uses vegetable tan liquors, this liquor should be mixed with the beamhouse wastes and settled in a pond or tank before the waste is discharged. Under some conditions it may be allowable to store the liquor in a tank and discharge it over a long period of time. It should never be discharged in a batch.

4. It is desirable under most conditions where chrome liquors are used for tanning to also mix these liquors with beamhouse waste and settle either in a pond or tank before discharging to a waterway.

Beet Sugar Factories

1. An effective screen shall be provided for the factory and process wastes from the manufacture of beet sugar. The screenings will be removed and disposed of on land or in any other satisfactory manner. It is suggested that the slot openings of the screen be ⅛ in. by ¾ in.

2. Steffens waste shall never be discharged to a State waterway. This waste must either be evaporated or ponded. In the latter case, it will be necessary to make arrangements with the Pollution Control Commission for the discharge of the ponded waste under controlled conditions, and during high-water periods.

3. Settling ponds shall be used for the removal of settleable material from factory and process waste. It is suggested that short-period ponds, constructed to operate in parallel, are more effective than large ponds operated in series. Certain of these ponds will be used until the material which settles starts to decompose. The waste will then be directed to other ponds.

Coal Washeries

1. Effective ponds will be provided for the removal of fine coal and dust before the wash waters are discharged to a stream. The detention period in the ponds will be as long as is possible, and will be established by agreement with the Pollution Control Commission.

Gravel Washeries

1. Effective ponds will be provided for the removal of sand and silt from gravel washings before the wash water is discharged to a waterway. The detention period will be as long as is possible and will be established by agreement with the Pollution Control Commission.

Flax Processing

1. The waste from the processing of flax will be impounded and discharged at high stream flows and under conditions controlled by the Pollution Control Commission.

Dehydration, Potatoes and Fruits

1. In cases where the skins of the potatoes or fruits are removed by means of abrasive equipment, a screen will be provided for the collection of this material and its removal from the water before discharge.

2. In case lime is used for the removal of skins, the waste from the process shall be ponded and discharged under controlled conditions by agreement with the Pollution Control Commission.

3. Peelings, cores, and rejects shall be removed in as dry a condition as possible and disposed of in such a manner as not to enter a waterway.

Metal Industry

1. The wastes from metal industries shall be corrected to a pH value within the limits of 6.0 and 9.0.

2. A concentration of toxic material will be regulated to come below the tolerance of aquatic life to those materials. For instance, in the case of cyanides, the concentration shall not be above 0.5 p.p.m. as KCN. In the case of chlorine, the concentrations shall not be above 1.0 p.p.m. Other tolerance limits for the metals, fluorides, etc., will be established at a later date.

Pulp and Paper Mills

Because of the size and the seriousness of the sulfite waste liquor problem, regulations concerning the disposal of this waste will be handled in a separate item and will not be included in this statement of minimum requirements. The following minimum regulations apply to the formation of the pulp sheet and to paper and board production:

1. Provision shall be made either by the installation of effective save-alls and/or by closing, or partially closing, the white-water system to reduce the fiber loss from beater and machine operations to 1 per cent of production.

2. Bark and knotty rejects shall be kept entirely out of State waters.

THE CHARACTERISTICS OF WASTES FROM CHICKEN PACKING PLANTS*

By H. Heukelekian, H. E. Orford, and J. L. Cherry

Respectively, Professor and Research Specialist in Sanitation, and Assistant Professor and Assistant Research Specialist in Sanitation, Rutgers University; and Veterinarian, Delaware State Board of Health

At the request of the Delaware State Department of Health, a cooperative study was undertaken for the purpose of ascertaining the nature and scope of the pollution problem arising from the wastes of chicken packing plants in Delaware. The investigation was of a general and preliminary nature and entailed studies of the plant processes, the strengths and flows of the various wastes, the effect of different types of treatment, and the effectiveness of existing waste treatment facilities.

Description of Processing

A chicken packing plant is a mechanized slaughterhouse, in which the chickens are killed, bled, picked, cleaned but not eviscerated, chilled, and frozen for shipment to retail outlets. Chickens so prepared are known as "New York dressed" chickens.

Chickens are received at the plant daily, and are kept in 4-tier, 16-compartment, movable, wire coops or batteries for about three days before slaughtering. Each battery houses approximately 100 birds, which are fed and watered.

The wire batteries have metal pans under the three top tiers to catch the droppings, whereas the bottom pans are left off and the droppings fall on the concrete floor. Continuous streams of water from hoses keep the floors clean and also raise the humidity in the structure.

From the feeder station the batteries are delivered to the killing room, where the chickens are hung by their feet on a moving overhead conveyor, which handles 30 to 150 birds per minute, depending on the plant. The chickens then pass through the following operations:

1. The throats are slit with hand knives.
2. The conveyor passes over a pit where approximately half the blood is drained and collected (about 1 oz. per chicken).
3. The chickens then pass through a long trough-like scalder, where hot water is constantly recirculated and continuously made up with fresh water.
4. The birds are then defeathered by mechanical pickers having rapidly rotating long rubber fingers, which beat and pick off nearly all the feathers. The few remaining feathers are picked by hand.
5. The conveyor next dips the birds in a tank containing a special molten wax, and then passes through cold water sprays, which set the wax.
6. Workers then strip off the wax, removing all the pin feathers from the chicken. The wax is refined and reused.
7. After stripping, the conveyor passes through an automatically operated singeing machine.
8. From the killing room the chickens pass to the packing room, where they are automatically sorted by weight and placed between layers of ice in 100-gal. hogsheads.

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.

9. Each hogshead, holding about 100 chickens, is filled with clean water and the birds are quick cooled 2 to 3.5 hr. to remove the body heat and bring the internal temperature to 36° to 40° F.

10. The hogsheads are then dumped, and the chickens inspected. Most of the birds are icepacked in celery crates, selling as ice-packed poultry.

Sources of Waste

The waste is derived from the following principal sources:

1. *Feeder Station:*—The liquid waste consists entirely of manure and spilled food washed from the floor. Because the bottom tier droppings fall directly to the floor, approximately one-fourth the manure is collected at this point and enters the liquid waste system. The volumes of waste are extremely variable and are determined mainly by the number of hoses left continually running between the floor washing operations.

2. *Battery Washing:*—Two types of battery washing are practiced—in one the whole battery is washed mechanically or manually; in the other the pans are removed, hand scraped, and pans and batteries washed by hand with relatively low-pressure hoses. In the former type of washing all the manure goes into the liquid waste and the total volume ranges from 100 to 200 gal. per battery. With scraped battery washing most of the manure is collected and does not enter the liquid waste, the volume ranging from 100 to 150 gal. per battery.

3. *Killing Room:*—The principal waste from the killing room floor comes from the scalder make-up water, which amounts to about 30 gal. per min. from a 60 chicken per minute conveyor line. This waste contains blood and dirt from the chickens. Other sources of waste are floor washings containing blood, feathers, and wax particles; also wax chilling water, which has little or no pollutional significance.

4. *Packing Room:*—The wastes from the packing room consist entirely of ice water dumped from the hogsheads and a small volume of floor washings. These wastes which are comparable to weak domestic sewage are of small pollutional significance, but comprise a large part of the total plant flow.

Composited samples of waste were obtained for analysis and experimental work. Two or three samples were procured on different occasions from each of three plants, and one sample from a fourth plant.

The methods of operation at the four plants studied are as follows:

Plant	Battery Scraped	Battery Washed	Chickens[1] Killed per Day
A	No	Manually	57,600
B	Yes	Manually	33,600
C	Yes	Manually	28,800
D	Yes	Mechanically	48,000

[1] Average live weight 3 lb. each.

Results

Flows

The flow from the different operations and the total flows from the four plants are given in Table I on the basis of gallons per 1,000 chickens (3 lb. average live weight) killed. The tabulation is divided on the basis of battery scraping procedure.

With the exception of plant D, which uses a mechanical method of washing batteries, the volume of water produced from battery washing and feeder station varies from 1,000 to 1,430 gal. per 1,000 chickens killed. The volume of waste produced from killing and picking room operation is smaller than that produced from battery washings and feeder stations with the exception of plant C, where apparently large volumes are used for this

TABLE I.—Average Flow, in Gallons per 1,000 Chickens [1] Killed

Source of Flow	Battery Not Scraped		Battery Scraped	
	Plant A	Plant D	Plant B	Plant C
Battery washing and feeder station	1,250	2,500	1,430	1,000
Killing and picking room	330	—	570	5,000
Packing room	1,040	—	1,430	1,000
Total flow	2,620	—	3,430	7,000

[1] 3 lb. average live weight.

operation. Packing room wastes contribute as much flow as the wastes produced from battery washings and feeder stations. The total flow varies from 2,620 to 7,000 gal. per 1,000 chickens killed, but if the 5,000 gal. produced from killing and picking room at Plant C is reduced to the volumes comparable to those in the other two plants the range of variation in total flow would be in the order of 2,620 to 3,430 gal. per 1,000 chickens killed.

Suspended Solids and B.O.D.

The suspended solids contents of the wastes from different operations are given in Table II. At plant A, where battery scraping is not practiced, the suspended solids from this source are extremely high. In plant D, where batteries are not scraped but are washed mechanically with about twice the volume of water, the suspended solids concentration is not higher than at plants B and C, where batteries are scraped. Naturally, the amount of suspended solids contribution from plant D is nearly twice as high as that from plants B and C. Similarly, the B.O.D. from battery washings was highest at plant A, where batteries are not scraped. It was relatively low at plant D, where batteries are not scraped, because of the large volume of water used in the washing operation. At plant C, where batteries are scraped more carefully taan at plant B, the B.O.D. was less than one-third of that at plant B. The suspended solids at plants A and B from killing and picking room wastes were about 6 times as high as those at plant C, where much greater volumes of water are used in this operation. The B.O.D. from the same operation varied in the same order as suspended solids, being lowest in plant C. The packing room wastes are relatively low in suspended solids and B.O.D. The battery wash-

TABLE II.—B.O.D. and Suspended Solids, in P.P.M.

Source		Battery Not Scraped		Battery Scraped	
		Plant A	Plant D	Plant B	Plant C
Battery washing and feeder station	S.S.	14,480	4,380	4,815	3,820
	B.O.D.	7,575	1,800	3,835	1,185
Killing and picking room	S.S.	1,697	—	1,482	257
	B.O.D.	1,208	—	1,730	321
Packing room	S.S.	—	—	272	83
	B.O.D.	—	—	309	132

TABLE III.—B.O.D. and Suspended Solids, in Lb. per 1,000 Chickens [1] Killed

		Battery Not Scraped		Battery Scraped	
		Plant A	Plant D	Plant B	Plant C
Suspended solids	Battery and feeding station	151	91	57	32
	Killing and picking room	4.7	—	7	11.7
	Packing room	2.4	—	3.2	0.7
	Total	158.1	—	67.2	44.4
B.O.D.	Battery and feeding station	78	37	46	10
	Killing and picking room	3.3	—	8.1	13.4
	Packing room	2.7	—	3.7	1.1
	Total	84.0	—	57.8	24.5

[1] 3 lb. average live weight.

ings and feeder station contribute the largest quantity of suspended solids and B.O.D., followed by killing and picking room wastes, and finally by packing room wastes.

The pounds of B.O.D. and suspended solids produced from various operations at the different plants are given in Table III. The greatest load is derived from battery washings, especially from unscraped battery washings. The total load of suspended solids produced at different plants varies from 158.1 lb. per 1,000 chickens killed at plant A, where batteries are not scraped, to 44.4 lb. at plant C, where batteries are scraped fairly well. Similarly, the B.O.D. load produced varied from a maximum of 84 lb. per 1,000 chickens killed at plant A to a minimum of 24.5 lb. at plant C. The percentages of the total suspended solids and B.O.D. contributed by battery washings at different plants illustrate in a different way the importance of battery scraping in the total pollutional load produced:

Plant	Susp. Sol. (%)	B.O.D. (%)
A	95.5	93
B	85.0	79.5
C	72.5	41.5

The p.p.m. B.O.D. and suspended solids of the total effluent from plant B are given in Table IV. These values were obtained (a) by making a mixture of wastes produced from the different operations on the basis of volume percentages in which they are produced and (b) by calculation from determinations of individual components. The two methods check closely.

Removal of Solids by Screens

A study was made of removals obtained by the wire baskets of the battery washings from plant B. A sample was obtained of the screenings removed and dry solids content determined.

TABLE IV.—Comparison of Artificial Mixture Made on the Basis of Flow with Calculated Values Obtained on the Basis of Individual Wastes Analyses

	Artificial Mixture	Calculated Values
Suspended solids (p.p.m.)	2,417	2,364
B.O.D. (p.p.m.)	2,300	2,010

The volume of material removed daily by the 4 baskets was estimated to be $3\frac{2}{3}$ cu. yd. Samples of influent and effluent from the baskets were also obtained and suspended solids removals determined. The results were as follows:

Volume removed by baskets (cu. yd./day)	3⅞
Net weight removed by baskets (lb./day)	6,230
Dry content of materials removed by baskets (%)	23.3
Dry content of materials removed (lb./day)	1,450
Susp. sol. in basket effluent (lb./day)	1,925
Removal calculated from materials in basket (%)	43
Volume of battery washings (gal.)	48,000
Suspended matter removed (calculated) (p.p.m.)	3,640
Suspended matter in basket influent (by analysis) (p.p.m.)	8,600
Suspended matter removed (by analysis) (p.p.m.)	2,950
Suspended solids removal (by analysis) (%)	36

On the basis of materials collected in the baskets the calculations show a removal of 1,450 lb. of solids daily, or 43 per cent of the input, giving a calculated removal of 3,640 p.p.m. On the basis of actual analyses of influent and effluent of the baskets a removal of 2,950 p.p.m., or 36 per cent, is obtained. In view of the sampling errors, errors in estimating the volumes of material collected by the baskets, and the assumption that the solids have a specific gravity of 1.0, there is good agreement between the values obtained by calculation and by analysis of influent and effluent samples. It is apparent that the installation of these baskets is justified for removal of a portion of the readily settleable materials from battery washings. The efficiency of the screens can be increased by increasing the detention period. These screens constitute, in fact, short period sedimentation tanks provided with a simple method of removing the solids. Other sludge removing mechanisms might be used, but because of the density of solids, removal by gravity or pumping would be difficult.

Removal of Suspended Solids and B.O.D. by Sedimentation

The average percentage removals of B.O.D. and suspended solids from the wastes produced from the various operations are given in Table V. The suspended solids removals from battery washings are high (84.5 to 95 per cent). The lower value is obtained from scraped battery washings. The suspended solids removals from killing room wastes in plants A, B, and C varied from 86 to 47 per cent. Similar variations were found in removals from packing room wastes (44.5 to 75.5 per cent).

B.O.D. removals obtained by sedimentation were lower than suspended solids removals. For battery washings the B.O.D. removals varied from 23.5 to 44 per cent; for killing room wastes, from 19 to 37.6 per cent; and for packing room wastes, from 20.4 to 33 per cent.

The suspended solids removals from the total plant effluent were 80 per cent and B.O.D. removals 40 per cent.

Volumes of Sludge Produced

The volumes of sludge produced by plain sedimentation are given in Table VI. The maximum volume of sludge

TABLE V.—Percentage Removal of Suspended Solids and B.O.D. by Sedimentation

Source of Flow	Battery Not Scraped				Battery Scraped			
	Susp. Sol.		B.O.D.		Susp. Sol.		B.O.D.	
Plant	A	D	A	D	B	C	B	C
Battery and feeder station	95	94	40	23.5	84.5	91	44	36.7
Killing and picking room	86	—	37.6	—	47	46.7	19	21.2
Packing room	—	—	—	—	75.5	44.5	33	20.4

TABLE VI.—Sludge Volume, in Ml. per Liter

Source of Flow	Battery Not Scraped		Battery Scraped	
Plant	A	D	B	C
Battery washing	256	320	102	51
Killing and picking room	20	—	30	5
Packing room	—	—	5	1.5

(320 ml. per liter) was produced from battery washings from plant D and the minimum volume (51 ml. per liter) from plant C. Killing room wastes gave sludge volumes varying from 5 to 30 ml. per liter. Packing room wastes had the least volume of sludge. The combined wastes gave a sludge volume of 47 ml. per liter.

To check the volume, quantity, and compaction of sludge a 20-l. mixture was made artificially from scraped battery washings and killing room wastes in proportion to their flows. The sludge volume produced after 1 hr. of sedimentation was 120 ml. per liter. The total quantity of sludge produced was placed in a 2-l. cylinder and the rate of compaction studied. The following volumes of sludge were obtained:

Time of Compaction (hr.)	Sludge Volume (ml.)	% of Initial	% Total Solids
Initial	2,400	—	1.9
1	1,280	53.5	3.5
2	1,200	50.0	3.8
24	700	29.2	6.6

The sludge volume decreased in 1 to 2 hr. to about half its original volume, and in 24 hr. to less than a third of the original volume. After 24-hr. compaction the sludge contained 6.6 per cent solids. The ash content of the sludge was only 10 per cent of the dry matter.

Chemical Treatment

Settled battery washings and killing floor wastes were treated with lime or alum. Lime up to 9 lb. per 1,000 gal. had little effect on the removals of suspended solids and B.O.D. Alum up to 13 lb. per 1,000 gal. removed substantial amounts of suspended solids, but very little B.O.D. Large volumes of sludge were produced. For these reasons chemical treatment of these wastes was not considered feasible.

Discussion

Reduction in Volume of Wastes

Considerable savings in the cost of treatment can be brought about by reduction in the volume of wastes. Such a measure by itself will not result in a reduction of the pollutional load, but does result in an increase in a concentration of the wastes. From the standpoint of detention time and size of tanks, considerable economies could be brought about by avoiding unnecessary use of water. It appears that where mechanical methods of washing the batteries are employed, larger volumes of water are used than by hand washing methods. There does not seem to be an appreciable difference in the amount of water used in washing scraped and unscraped batteries. A figure of 1,500 gal. per 1,000 chickens killed (average live weight 3 lb.) can be used for design calculations of the flow from the battery washings, based on the most reliable figures obtained. It might be possible to reduce this figure further by better methods of scraping and washing the batteries. Another source of water is from the feeder station floor washings. The amount of water used for washing the floors is dependent on (a) the manure droppings from bottom tiers in the batteries and (b) water used to humidify the air. If the manure can be prevented from dropping on the floor, by redesign of the batteries, the volume of water used to remove the manure from the floors can be reduced. By installation of humidifying units, the use of water on the floors for humidifying the air can be eliminated.

Excessive volumes of water were obtained from the killing and picking room of plant C. The reasons for this are obscure. A figure of 600 gal. per 1,000 chickens killed, based on plant B flow, can be used as a design basis. This probably cannot be reduced greatly, except for segregation of wax chilling water. If this were done, the wax could be screened out from the chilling water and the water discharged without further treatment.

Not much reduction of packing room wastes is possible because of the fixed flow from chilling barrels, but elimination of continuously running hoses could reduce the flow.

Reduction in Strength of Waste

An immediate and imperative measure to be taken for the reduction of strength of the waste is elimination of manure from battery washings and from feeding station floors. Complete elimination of manure from these two sources would be equivalent to a treatment plant with 90 to 95 per cent efficiency of suspended solids and B.O.D. removal. On the basis of complete elimination of wastes from these two sources, the suspended solids load would be reduced from 158 lb. to 7 lb., and B.O.D. load from 84 lb. to 6 lb. per 1,000 chickens killed. Killing and packing room wastes would then contribute suspended solids of 7 to 10 lb. and B.O.D. of 6 to 18 lb. per 1,000 chickens killed. Complete removal of manure may not be feasible, but if 90 per cent of the manure could be prevented from discharge into the sewer, it would contribute about 15 lb. of suspended solids and 8 lb. of B.O.D. per 1,000 chickens killed. Addition of these quantities to the suspended solids and B.O.D. contributed by the killing and packing room wastes would produce a total waste with about 25 lb. of suspended solids and the same amount of B.O.D., as compared with 158 lb. of suspended solids and 84 lb. of B.O.D. discharged in present practice. That scraping the batteries, as practiced at plants B and C, does not remove all the manure is shown by the 32 to 57 lb. of suspended solids and 10 to 46 lb. of B.O.D. contributed by battery washings and feeder station wastes at these two plants. Even at these two plants, the quantity of manure entering the sewer must be reduced considerably before the 90 per cent reduction suggested above can be attained. It seems unjustifiable to add the manure to the sewer and pay heavily for its treatment. The manure after being added to the sewer produces larger volumes of sludge, thereby increasing the cost of sludge disposal facilities. The moisture content of the manure if scraped dry is lower than that of the sludge that forms from the battery washings after settling. It also imparts B.O.D. and suspended solids to the waste after sedimentation, thus necessitating larger and costlier secondary treatment facilities.

The present methods of scraping the battery pans are crude and the operation is careless, resulting in needless loss of manure. The battery pans should be scraped as thoroughly and completely as possible, either manually or mechanically, without the use of water. After all the manure that can be removed in this way is taken off from the pans, water can be used to wash them. A high-pressure squirt spray wash, using ½ gal. of water per pan, could do the job. This water should be kept apart from the manure and also from the rest of the plant wastes, and can be discharged directly to a digester. The battery pans can be scraped mechanically by rubber fingers or some other suitable mechanical means while being carried on a conveyor belt.

The other source of manure, droppings on the floor of feeder station, can be eliminated by using pans in the bottom tier. If this is not possible with present equipment, either the batteries can be redesigned or the floors

can be scraped before washing. The manure collected could be dried in a central drying plant, which would serve all the packing plants in the area. The dried product can be sold as fertilizer. If this cannot be done the manure collected can be spread on the fields in its wet condition.

Considerable reduction in B.O.D. could be effected by keeping as much blood out of killing room wastes as possible. Dripping of blood on the floors should be prevented, and the clotted blood removed before floor washing to the drains. Screens to catch feathers and wax before they enter the systems are necessary to eliminate difficulties in the operation of subsequent treatment units. Reduction in strength of packing room wastes is not essential, as these wastes contribute only small amounts of suspended solids and B.O.D.

Segregation of Wastes

After the improvements are made to eliminate as much waste as possible from battery and floor washing, there will still be some waste originating from these sources. The strength of these wastes will depend on the measures taken and is difficult to predict. The pollutional materials contained in these wastes should be treated together with the killing and picking room wastes. Both wastes have settleable solids and B.O.D. and can best be treated in combination by the same units. For partial treatment, it might be desirable to segregate the packing room wastes from the rest of the flow. The flow from the packing room is considerable, and the waste is relatively weak, and low in settleable solids. For complete treatment, however, packing room wastes should be handled with the rest of the plant wastes.

Pretreatment of Wastes

The basket screens are effective in removing solids from battery washings. Their necessity will depend on the effectiveness of the elimination of manure from battery washings and feeding floor wastes. When this is achieved there will be little need for them. Under present conditions of manure losses, either with or without scraping of the battery pans, they have a useful function.

Plain Sedimentation

The minimum treatment of wastes arising from chicken packing plants should be plain sedimentation. Sedimentation is also necessary in conjunction with secondary treatment. Expected removal by sedimentation is 85 to 90 per cent of suspended solids, if battery washings contribute a great deal of manure, and 60 to 65 per cent when most of the manure is eliminated from the waste. Not more than 30 to 35 per cent B.O.D. removal is expected by sedimentation, whether manure is present or not.

Secondary Treatment

As a part of the general program of alleviation of pollution and nuisances created thereby, secondary treatment of the waste is necessary. Of the different possibilities available, high-rate trickling filters are most feasible and economical. Sand filtration is not suitable because of the clogging problems that will arise, the high cost of construction, and the large areas required.

The quality of the effluent will be affected directly by the strength of the waste to be treated, which in turn is dependent on the prevention of unnecessary losses of manure and blood from the plant. It is difficult to predict what the quality of the effluent will be without reference to the strength of the waste to be treated. If the suspended solids of the waste are assumed to be 1,500 p.p.m. and the B.O.D. 1,000 p.p.m., an 80 per cent removal of suspended solids by sedimentation and an additional 80 per cent removal by high-rate filtration might be expected.

No laboratory experiments with trickling filtration of this waste have been performed, but in view of the observation that, after sedimentation for 1 hr. there is additional removal of finely divided solids by further storage, it is expected that the removal of solids by trickling filters will be high. The high percentage removals by chemical treatment further confirm this view. On the basis of the above assumption an effluent containing 50 to 100 p.p.m. suspended solids may be expected after high-rate filtration and secondary sedimentation. The B.O.D. of the effluent will be about 100 p.p.m. If a weaker raw waste is obtained by proper housekeeping as suggested, the quality of the effluent will be somewhat better. However, the greatest advantage from this action will be in the lower capacities and sizes required for the different units.

A flow of equalization pit ahead of the filters to permit 24-hr. operation of these units is essential to prevent temporary overloading of the filters and to keep the size of the filters at a minimum.

Sludge Digestion

The disposal of sludge from primary and secondary clarifiers is a major problem because the quantity of sludge expected is large and the sludge is highly putrescible. The recovery of the manure, which contributes the major portion of the solids, is, therefore, very important from the standpoint of the cost of sludge disposal facilities. Observations on existing sludge lagoons have shown that the sludge digests readily. Under controlled conditions there should be no difficulty in obtaining satisfactory digestion. Open pits might be used for the digestion of sludge from primary and secondary clarifiers but, because of inadequate methods of adding and withdrawing sludge and supernatant liquor, it is not expected that these units can be operated properly and give satisfactory results. It will be a natural tendency to let the sludge accumulate and fill up the tanks, and it will be difficult to locate the supernatant liquor level.

The digested sludge from the tanks can be drawn to sludge drying beds. The sludge should be non-offensive and after dewatering and drying on the beds can be readily disposed of on fields without creating nuisance.

Summary and Conclusion

A survey of the pollution problem arising from chicken packing plants was made on a cooperative basis with the Delaware State Department of Health. The latter organization furnished the information regarding the processes and flows, and collected and delivered the samples. Laboratory analyses were made of the samples furnished and experimental work was undertaken with the idea of determining the amenability of the wastes to certain types of treatment. The results warrant the following conclusions:

1. Flows from different plants vary within wide limits. Total flows varied from 2,600 gal. to 7,000 gal. per 1,000 chickens (3 lb. average live weight) killed at different plants. The high value was due to the large volume of waste arising from killing and picking room wastes from one plant. With that exception the total flows vary from 2,500 to 3,500 gal. per 1,000 chickens killed. Flows from battery and feeder station and packing room are higher than those from killing and picking rooms.

2. The wastes received from the same plant at different times, and from different plants, vary in strength.

3. Major portions of the B.O.D. and suspended solids are derived from battery washings (manure).

4. Scraping the battery pans by the present methods reduces the pollution somewhat.

5. Better methods of scraping the pans are needed to decrease the pollution load further.

6. The pollution load can be decreased further by preventing manure from dropping to the floor from the bottom tier of batteries.

7. For the combined wastes where all the manure is discharged, the population equivalents per 1,000 chickens killed are 500 for B.O.D. and 800 for suspended solids, and are 147 and 220, respectively, when part of the manure is removed. When all the manure is removed, the rest of the wastes have a population equivalent per 1,000 chickens of 53 for B.O.D. and 39 for suspended solids.

8. Sedimentation removes an average of 92 per cent of suspended solids of battery washings and 60 to 65 per cent of killing and packing room wastes. The removal of suspended solids from mixed wastes by sedimentation was 85 per cent. The B.O.D. removal by sedimentation of battery washing, killing room, and packing room wastes was of the order of 25 to 35 per cent. A major portion of the total residual B.O.D. after sedimentation was due to that contributed by battery washings.

9. Large volumes of sludge were obtained by sedimentation of the mixed wastes, the preponderance of which was due to battery washings. Scraping the batteries reduced the volume of sludge. The sludge compacted readily to over 6.0 per cent solids after 24-hr. storage.

10. The percentage of ash in the suspended solids from the wastes and in the sludge produced by sedimentation is low (around 10 per cent).

11. The sludge rapidly becomes putrescible.

12. Laboratory experiments of chemical treatment of the settled waste showed that alum treatment resulted in substantial removals of suspended solids from battery washings and killing room wastes. Lime was not so effective. Neither chemical gave an appreciable reduction of B.O.D. Large volumes of sludge were produced.

13. Wire screens, as employed for the removal of solids from battery washing, gave 35 to 45 per cent removals of suspended solids.

14. Sand filtration of the settled mixed wastes resulted in rapid clogging of the sand and impaired the efficiency of B.O.D. reduction.

15. Digestion of the sludge is feasible.

WASTES FROM POULTRY DRESSING ESTABLISHMENTS

By Ralph Porges

Sanitary Engineer, U. S. Public Health Service, Kansas City, Mo.

During an investigation of water pollution in the Kansas River Basin (1) numerous poultry dressing establishments were appraised to determine the amount of pollution produced. A paucity of information regarding wastes discharged from poultry processing made it imperative that studies be conducted for the development of production unit pollutional factors. Studies were made over the operating cycle of several poultry dressing establishments to develop unit production pollutional factors.

Method

Several plants were selected and information on production figures, water consumption, and plant operation was collected from plant officials and operating personnel. The feasibility of sampling was investigated and, where necessary, discharge lines were cleaned, additional valves and meters were installed, and extra records were developed for the study.

The usual procedure was to establish a flow gaging station, installing a weir whenever possible, and check waste discharges against water meter readings. Survey personnel were then assigned specific posts and duties so that meters, weir readings, flow measurements, and sampling were coordinated at 15-min. intervals throughout the entire period of operations. Individual samples were composited according to flow to secure a representative discharge. Composite samples were stored in an iced container throughout the sampling period and while enroute to the laboratory.

Laboratory analyses, which were performed according to "Standard Methods" (2), consisted of the following determinations:

1. pH
2. B.O.D. (standard 5-day, 20° C.)
3. Suspended solids (total, fixed, and volatile)
4. Turbidity
5. Chlorides
6. Alkalinity

Description of Process

Poultry dressing establishments act as receiving stations for the birds, and provide for their slaughtering, dressing, and packing. The plants studied employed from 7 to 51 workers and operated from 4 to 7.5 hr. per day. Normal operation, provided enough birds are on hand, is an 8-hr. day plus 1 or 2 hr. for clean-up. Most establishments show a seasonal variation in production, with the peak developing during the late summer and extending into November and early December.

At the start of operations the poultry batteries are taken from an adjoining storage space to where the birds are removed and suspended from shackles on an endless chain leading to the killing floor. After being stuck, the birds pass through a scald tank and then to the roughing machines, which remove the feathers. Several types of roughing machines are employed, according to the portion of the bird being cleaned, such as neck, leg, and wing machines. Some plants utilize a wax dip for the removal of the finer and pin feathers, the birds being dipped into a hot wax

tank, cooled by a water spray and the wax and feathers removed by hand. The wax is then heated, filtered, and re-used. Following this the birds are hand picked and may then pass through a singer, following which they are washed.

The birds are packed without evisceration in the so-called "New York pack." The "full pack" process includes the removal of entrails, washing the birds, and final packing.

Production

Poultry will vary on the average from 4 to 4.5 lb. per bird, the average of the four plants studied being 4.35 lb. This compares favorably to 4.5 lb. per bird reported in the Ohio River Pollution Survey (3). The birds dressed "New York pack" about ½ lb. less, for an average shrinkage factor of 12.1 per cent. Shrinkage for "full pack" will vary from 20 to 22 per cent. These data are shown in Table I.

The number of employees per unit production is presented in Table II. An average of 14.5 employees may "New York pack" 10,000 lb. of birds per day.

Sources of Wastes

Wastes are produced from the storage of live birds and the processing of the fowl.

TABLE I.—Weight of Birds, Live and Dressed

Plant	Av. Wt. per Bird (lb.)			Shrinkage	
	Live	N.Y. Pack	Full Pack	Lb.	%
A	4.35	3.73		0.62	14.3
B	4.00[2]	3.52[2]		0.48	12.0
C	4.58		3.66	0.92	20.0
D	4.45	4.00		0.45	10.1
Average	4.35[3]				

[1] Springers, 3.18 lb.; fowl, 4.95 lb.
[2] Springers, 2.76 lb.; fowl, 4.40 lb.
[3] 4.5 lb. per bird, Ohio River Pollution Survey (3).

TABLE II.—Number of Employees per Production Unit of 10,000 Lb. Live Weight per Day

Plant	Type of Process	Employees per Unit
A	N.Y. pack	13.1
B	N.Y. pack	14.5
C	Full pack	26.4
D	{75% N.Y. pack {25% Full pack	15.8

Receiving

The birds are usually kept in storage overnight, or until sufficient numbers are received to permit a day's operation. Wastes consist of manure from the batteries, waste feed make-up, and floor washings. Many plants eliminate manure from stream pollution considerations by trucking it to a dump. Other plants clean the batteries by scraping the waste to a sump and flushing it to the sewer.

Killing Floor

Most plants allow the blood to coagulate, thereby permitting its removal after completion of operations. It may be taken to a dump, to a rendering plant, or may be sold or given away for fish bait. Obviously, some blood in all plants reaches the sewer, whereas a few establishments dispose of it all in that fashion.

Scald Tank and Roughing Machines

The scald tank is made up with boiling water prior to operations and maintained at that temperature. A constant stream of water enters the tank and overflows, usually to a floor drain. Some blood and miscellaneous matter contaminate the tank water as the fowl pass through. The vat is dumped at the end of the operating day and a highly polluting waste is discharged. The roughing processes operate with continuous water sprays discharging to floor drains.

TABLE III.—Poultry Dressing Wastes per Production Unit of 1,000 Lb. Live Weight

Operation	Waste Flow (gal. per unit)	Analyses (p.p.m.)		Sewered Pop. Equiv. per Unit		Remarks
		B.O.D.	Sus. Solids	B.O.D.	Sus. Solids	
Plant A N.Y. pack	435	997	960	22	17	Most blood saved
Plant B N.Y. pack	1,850	1,475	1,520	136	117	Cooling water; 2 days' manure to sewer; most blood saved
Plant C N.Y. pack	545	1,070	1,052	29	23	Some blood to sewer
Plant C Evisceration and packing	202	1,560	640	14	5	Kill shown above drawn
Plant D 75% N.Y. pack 25% full pack	1,150	290	502	17	24	Cooling water; minimum of blood
—	2,200	2,730	1,460	300	160	Ohio River Pollution Survey (3)
Blood	6.7	92,000	—	30	—	Volume estimated

Waxing

Most of the wax is reclaimed. In most instances the feathers are taken to a dump. Wastes consisting of wax and feathers reach the sewer inadvertently.

Evisceration

When poultry is drawn, blood, bits of fat, and meat scraps are washed to waste. Obviously, entrails should never be discharged to sewers, although this practice may be encountered occasionally.

Miscellaneous

The crop is milked by puncturing, and its contents are removed. Usually the waste drops to a container to permit easy removal, although occasionally this waste may reach the sewer.

Wash waters and equipment and floor clean-up may also contain considerable wastes.

Quantity and Character of Wastes

The volume of combined wastes from the various plants is shown in Table III. The analyses of combined wastes are shown in tables III and IV. It may be noted that the wastes are several times the strength of domestic sewage. The alkalinity and chloride analyses are not shown in Table IV, as these substances in the water supply overshadow the amount produced during the process.

TABLE IV.—Laboratory Analyses

Plant	B.O.D. (p.p.m.)	Suspended Solids (p.p.m.)			pH	Turbidity (p.p.m.)
		Total	Volatile	Fixed		
A	997	960	820	140	7.1	1,100
B	1,475	1,520	1,120	400	7.5	2,200
C	1,070	1,052	932	120	7.6	900
C	1,560	640	490	150	6.7	500
D	290	502	406	96	7.6	500

Receiving

The discharge to sewers of manure from receiving and feeding stations is the largest single source of pollution from poultry dressing establishments. However, this source of pollution may readily be eliminated by removing the material and dumping or returning it to the farms as fertilizer.

Plants A and B (Table III) had similar operational methods, but the latter plant wasted manure to the sewer. On the day of testing, approximately 2-days' accumulation of manure was discharged, resulting in an increase of about 110 in the population equivalents per 1,000 lb. live weight. Thus, it appears that the manure each day from 1,000 lb. of birds will approximate a population equivalent of 55.

Killing Floor

The blood from the killing of the birds appears as the second largest source of pollution. Approximately 8 per cent of the body weight of chickens may be blood (4), of which possibly 70 per cent will drain. Therefore, for each 1,000 lb. killed 56 lb. of blood will be discharged. A 5-day, 20° C., B.O.D. test of chicken blood showed 92,000 p.p.m. This compares favorably with the 80,000 p.p.m. reported for chicken blood by Stoltenburg (5) and with that given by Bates (6) as "over 100,000 p.p.m." for packing plant blood. The resulting population equivalent is approximately 30 per 1,000 lb. live weight.

Catching the blood for disposal by means other than sewerage will eliminate this important pollutional factor. Many plants remove the blood that coagulates and thereby eliminate a large part of this waste.

Scald Tank and Roughing Machines

The scald tank receives considerable blood, some manure, and miscellaneous dirt that may wash from the feathers. The tanks have a constant overflow and are dumped at the end of the day. The pollution from this tank could be reduced by extending the time the blood is allowed to drain from the birds.

Wastes from the roughing machines contain some dirt and feathers. Adequate screening on floor drains will prevent most of this material from reaching the sewer.

Waxing

Occasionally, wax and feathers in the sewers create difficulties. Although the B.O.D. may not be increased appreciably, sewers and appurtenances become clogged. These substances also impede proper sewage treatment plant operation, principally because they clog screens, weirs, nozzles, pumps, etc., and interfere with the proper working of settling tanks and digesters.

Evisceration

At one plant separate wastes were obtained from the evisceration process. Results indicated a population equivalent of 14 per 1,000 lb. live weight.

Sewered Population Equivalents

Table III shows the sewered population equivalents for the plants surveyed and a value obtained from the summary table, Supplement D, Industrial Waste Guides—Ohio River Pollution Survey (3). These are based on a per capita discharge per day of 0.167 lb. of 5-day 20° C. B.O.D. and 0.2 lb. of suspended solids. The population equivalent value from the Ohio River Pollution Survey Report probably reflects a difference in the type of operational methods encountered. It appears reasonable that if the waste includes high oxygen demanding materials, such as accumulated battery manure and a portion or all of the entrails, a population equivalent of 300 or more per 1,000 lb. of live fowl handled may be realized.

From Table III, the population equivalents shown in Table V for poultry dressing practice in the Kansas River Basin area appear reasonable, and will provide tentative unit values,

TABLE V.—Population Equivalents per Production Unit of 1,000 Lb. Live Weight

Type of Process	B.O.D.	Susp. Sol.
New York pack; no manure, most blood saved	25	20
Manure per day	55	50
Blood	30	—
Evisceration and final pack	15	5

pending additional studies, for the pollutional evaluation of poultry dressing plants.

Pollutional Effects

It would appear that poultry dressing wastes are similar to those normally encountered at slaughterhouses and meat packing plants and that similar treatment devices would take care of these wastes. Oxygen depletion, sludge deposition, and coloration are the principal effects of these wastes on receiving bodies of water.

Acknowledgments

These studies were conducted as part of a water pollution investigation of the Kansas River Basin which developed under a cooperative agreement between the Corps of Engineers, the Bureau of Reclamation, the Kansas State Board of Health, the Nebraska State Health Department, and the Missouri Drainage Basin Office of the Public Health Service.

Special acknowledgment is made to the field staff assisting in these studies, including Public Health Service personnel and representatives of the state health departments concerned, and particularly Public Health Engineer R. M. Babcock, Nebraska State Health Department, and Sanitary Engineers Geo. A. Hussey and R. D. Lee, Kansas State Board of Health. Acknowledgment is also made of the valuable contribution by the technical staff of the Environmental Health Center, Public Health Service, Cincinnati, Ohio, for their critical review of this article.

Analyses were conducted by a Public Health Service field laboratory and the Kansas State Board of Health Laboratory at Lawrence, Kansas.

Cooperation by industry in all instances was excellent.

References

1. "Kansas River Basin Water Pollution Investigation." Missouri Drainage Basin Office, U. S. Public Health Service (June, 1949).
2. "Standard Methods for the Examination of Water and Sewage," Ninth Edition. American Public Health Association (1946).
3. "Industrial Waste Guides, Ohio River Pollution Control." U. S. Public Health Service, *House Doc. 266, 78th Congress, 1st Session*, 1034 (1943).
4. Dukes, H. H., "The Physiology of Domestic Animals," p. 54. Comstock Publishing Co., Ithaca, N. Y. (1937).
5. Stoltenburg, H. A., Kansas State Board of Health, Unpublished Data.
6. Bates, R. W., "A Discussion of Packing Plant Waste Disposal." *Iowa Sewage Works Digest* (Oct., 1948).

HIGH-RATE TRICKLING FILTER OPERATION ON FORMALDEHYDE WASTES *

By B. W. Dickerson

Sanitary Engineer, Hercules Powder Co., Inc., Wilmington, Del.

The Mansfield plant of Hercules Powder Company produces synthetic resins and constituent products required in their manufacture. The wastes resulting from manufacturing operations were originally discharged without treatment into a small stream known as the Rumford River. With the enactment of stream pollution control measures, the problem of waste disposal became paramount.

Late in 1946 studies were inaugurated at the plant to determine the magnitude of the problem and methods for its reduction or elimination. A report on this work has been covered in a preceding paper (1). However, it may be well to review some of this work so that a comprehensive picture of the problem and its solution may be presented.

The plant wastes contain varying amounts of rosin oils, dilute formaldehyde, pentaerythritol, sodium formate, phenols, organic acids, and sanitary sewage. In addition, the plant discharges large quantities of uncontaminated cooling water. All of the liquid wastes are on the acid side, having pH values dropping below the methyl orange end point. With the exception of the sanitary sewage all are in solution. The oils are partly in suspension and partly in emulsion, depending on process operations.

The original plant sewerage system comprises two collection systems, one for sanitary sewage and the other for both contaminated and uncontaminated process waste waters.

A study of the plant wastes indicated a total B.O.D. load of 2,000 lb. per 24 hr., with individual B.O.D. values ranging from 300 to 10,000 p.p.m. Formaldehyde concentrations ranged up to 5,000 p.p.m. and were the major portion of the load. The total volume was approximately 500,000 g.p.d. The quantities present of rosin acids and oils, as well as phenols, were variable, depending on resin manufacture. Floor washings comprised mainly sodium formate and pentaerythritol resulting from spills and leakage. Because formaldehyde comprised about 90 per cent of the load and was a toxic compound, the major concern was directed toward means for its destruction.

As a first step in reducing the pollution, treatment of the sanitary wastes was effected by installation of a septic tank followed by chlorination with sodium hypochlorite.

Experimental Investigations

Laboratory studies were made covering every known method of chemical treatment to provide destruction of the formaldehyde. This work showed that there was no satisfactory treatment, from the standpoint of either economy or end product, as many final products were far more difficult to handle than the original material. An attempt was made to break it down by anaerobic digestion, but this also failed. Pilot plant work on a low-rate trickling filter provided good reductions for about two months. Then in about two days all the bacteria died, which ended that phase of the program. Pilot plant work was again started employing a

* Presented at 22nd Annual Meeting, Federation of Sewage Works Associations; Boston, Mass.; October 17–20, 1949.

high-rate trickling filter, this method providing not only good reductions but also the solution to the problem.

The filter unit employed was constructed of 10-in. terra cotta pipe having a depth of 6 ft. and was packed with stone obtained from the trickling filter at the municipal disposal plant. It was operated at a rate of 50 m.g.a.d. and with about a 40 to 1 recycle ratio. The system was provided with a settling basin of conventional design having a total retention period of 15 min. The pH of the formaldehyde solution was corrected to about 7.0 with aqueous ammonia and was fortified with the same nutrients and in the same ratios as required for the "standard" B.O.D. dilution water (2). In addition, ammonium phosphate was added to provide a 25 to 1 total carbon to nitrogen ratio.

The system was operated for a period of several months with formaldehyde concentrations ranging up to 2,050 p.p.m. in the main feed tank. Bacterial growths were developed on the filter that would live on the formaldehyde and break it down. Filter efficiencies were low, averaging about 25 per cent. However, over-all plant efficiencies ranged up to 94 per cent. Formaldehyde removals varied from 0.73 to 2.59 lb. per cu. yd. of filter stone, depending upon applied concentrations. This work indicated conclusively that formaldehyde was amenable to biological treatment for its destruction.

Further work using a composite feed simulating plant wastes indicated that these were also amenable to biological decomposition.

During this period of pilot plant operation, studies were made on the possibilities of lagooning the filter effluent to promote further reduction in formaldehyde concentration. These showed that biological action still persisted in the lagoon and that an additional 95 per cent reduction could be accomplished in 13 days. From this work it was felt that the full-scale plant should be followed by a lagoon before the effluent was discharged to the river.

Plant Studies

The first step in the plant program was segregation of contaminated and uncontaminated waste waters. This necessitated the installation of a new plant sewerage system for contaminated wastes. In addition, all barometric condensers installed on the several steam vacuum jets were replaced with surface condensers to reduce the volume of contaminated water. The septic tank effluent was reconnected into the main sewer to the new treatment works. An oil separator was installed on the effluent from the resin manufacturing building for removing floating oils and resins.

Before designing the treatment plant, a restudy was made of all wastes to see whether or not any could be reused in process operations. Several places were found where reuse could be made and these were accordingly repiped. In addition, certain sludges which were being discharged into the sewerage system and were carried by the large volume of cooling water, were repiped so that they could be discharged separately to a disposal area. When this program was finished, the total load had been reduced to a maximum of 300 lb. of formaldehyde, or about 675 lb. of B.O.D. per day. Of the 675 lb. of B.O.D., 600 was due to the formaldehyde and the remainder to organic wastes. The total flow averaged about 40,000 g.p.d., or about 8 per cent of the original combined flow.

Design and Construction

Filter

In the design of the waste treatment plant the first step was the filter. This was designed on the basis of formaldehyde. A value of 1.25 lb. per cu. yd. (equivalent to 2,000 lb. per acre-ft.) was used. This value was taken from the original pilot plant studies. A 6-ft. stone depth was felt satisfactory and the unit was made 37 ft. in diameter. On the basis of B.O.D., the loading was 2.8 lb. per cu. yd., equiva-

lent to 4,500 lb. per acre-ft. Because 89 per cent of this was formaldehyde, the loading was not felt excessive.

In order to provide for good ventilation, the ends of the filter underdrains were left open and a concrete ring was poured on top to provide the base for the wood staves forming the sidewall of the filter unit.

The filter unit was designed for a 50-m.g.a.d. rate of application. The rate as finally set was 900 g.p.m., equivalent to 52 m.g.a.d. A four-arm reaction distributor designed to take the flow directly from the circulating pumps was selected. The stone selected was carefully screened traprock having a maximum size of 5 in. and a minimum size of 3 in. The filter was constructed so as to provide gravity flow from it to the settling basin.

Settling Basin

The settling basin was designed on the basis of 15 min. retention. A rectangular 15,000-gal. concrete tank 9 ft. deep was available in the area where the treatment works were to be installed. It was considered satisfactory and was accordingly equipped with the necessary inlet and outlet works, scum drawoff, and sludge collecting mechanism. A sloping concrete floor was installed in the bottom, terminating in four sludge pockets at one end. Sludge drawoff lines were installed in each and provided with full-opening plug cocks for control. These all discharged into one common header which conveyed the sludge to the well in the pump house.

Pump House and Sludge Disposal

The main pump house was arranged to hold the filter circulating pumps, sludge pump, and effluent pumps. It was provided with three wet wells—one to receive the basin effluent and incoming raw waste, one the sludge, and one the settled effluent taken a short distance ahead of the overflow weir in the settling basin. With the use of the lagoon for final treatment, it was desired to provide ample bacteria in the plant effluent for continuous seeding.

The sludge problem was given considerable thought. Pilot plant operations had produced such small volumes that thorough studies could not be made. At another plant, where only resins were made, sludge studies had indicated that the material was not amenable to anaerobic digestion. It was believed that this would probably be the case here. As the manufacturing plant had a disposal area for sludges it was decided to haul the sludge from the treatment plant to this area until a definite solution to the problem could be made.

Lagoon

The final lagoon was constructed of earth, adjacent to the river. It was 75 ft. by 150 ft. and 4.5 ft. deep. With a capacity of 380,000 gal., it provided 9.5-day retention at normal rating. Lagooning studies had indicated 85 per cent reduction in 10 days and as this area was all that was available it was felt the 9.5-day period would be sufficient. The effluent was withdrawn over a weir and discharged into the uncontaminated effluent from the plant just prior to its discharge into the river. Figure I shows the treatment plant and lagoon at this stage of the development.

Chemical Equipment

Serious consideration was given to the need for a compositing basin on the raw waste line prior to discharge into the main wet well. Studies of process operations indicated that there would always be a flow of formaldehyde waste into the system and resin wastes would form only a small portion of the total. It was believed, therefore, that the system would be adequate for handling the intermittent resin discharges. It was kept in mind that if this condition changed, an equalizing tank would be needed and another pump would be re-

FIGURE 1.—High-rate trickling filter plant and lagoon for treatment of formaldehyde wastes.

quired. Space was left for this pump in the main building.

pH correction was required on all waste waters except sanitary sewage. Experience had shown that neutralization of formaldehyde by any sodium alkali would produce sodium formate in the reaction. Tests had shown this to be more toxic than formaldehyde. Inasmuch as nitrogen was required in the system, the use of aqueous ammonia seemed most suitable. It would provide the required nitrogen and was excellent for pH correction.

Aqueous ammonia was easily obtainable in 55-gal. drums at 29.3 per cent strength, and could be fed by means of diaphragm pumps. The units as actually installed comprised a 75-gal. closed steel tank vented to the outside atmosphere and fitted with necessary gage glass. A proportional chemical feeder was used to meter the ammonia solution and deliver it into the waste stream. The full strength solution was used with no dilution.

Because manufacturing schedules varied in the several process buildings, pH correction of individual wastes was handled at each building. Alkali requirements were sufficiently constant at each building that a constant-rate feeder, which could be controlled by one of the process operators, was satisfactory. This eliminated costly and complicated automatic equipment at the waste treatment plant.

Initial Operation

Construction was completed and the plant ready for initial operation late in August, 1948. In starting up, it was felt that the best procedure was to develop a growth on the filter stone using organic materials easily available, and then redevelop this growth for the actual conditions of operation. Although sludge from the local municipal sewage plant was available, the psychological problem arising from its handling was accentuated by the high incidence of poliomyelitis and it was felt some other means should be used. Manure from a large stable was available, so it was

used. It was placed in a wire-screen basket set in a manhole in the return line from the filter to the settling basin. Here, the recirculated water leached out the organic material. To provide additional nutrients, 10 gal. of skim milk were added to the system each day.

During the initial period the rate of application to the filter was held at 5 m.g.a.d. The initial operation took about 3 weeks to develop filter slimes considered sufficiently strong to allow application of plant wastes. From pilot plant experience it was known that before satisfactory operation could be obtained, the existing bacteria would have to be redeveloped to the formaldehyde environment. The slimes as originally developed were dark brown in color, a large proportion appearing to be molds and fungi.

Plant wastes were first introduced in small increments at intervals during the 8-hr. day. Later, the addition was continuous at a low rate of feed during the day. After about two weeks the low rate was maintained continuously throughout the 24 hr. After a week's operation at this rate the feed was gradually stepped up over a period of a week so that the plant was taking the whole load. There was considerable sloughing during the early application of wastes, but this diminished as time passed. A part of the sloughing could be attributed to the increase in rate of application to the filter, as it was raised from 5 to 52 m.g.a.d. in about 5 days. There was some additional sloughing during the first few days of full-load operation.

As the plant wastes were admitted the bacterial growth on the stone increased in thickness and the color changed to a very light brown with large patches of yellow. Here and there the stones were covered with growth having more the character of an icy coating, sometimes with a slight pink cast. These growths were characteristic of those developed in the pilot plant when handling only formaldehyde. It was expected that the same color characteristics would develop in the slimes in the full-scale plant as in the pilot unit, but the same coloring was never obtained during the whole period resin plant wastes were a part of the total. No B.O.D. tests were made during this period. However, formaldehyde determinations were run after the first week of plant waste additions. It was not until the plant had been taking the full load for over two weeks that any reductions were obtained.

As soon as full plant load was being applied to the system, diammonium phosphate was added to the main wet well to provide approximately 0.02 p.p.m. phosphorus per p.p.m. carbon.

During the initial starting period no pH adjustment was made on the water in the system. However, when the plant wastes were admitted these were corrected at the source, and the composite to the treatment plant averaged about 8.0.

There was considerable variation until the full plant load was being taken. Then, after several days, the pH gradually settled to 7.8 and fluctuated only one or two tenths, unless the incoming pH rose above 8.7 or dropped below 6.8. This condition existed until the resin manufacturing wastes were eliminated and formaldehyde was the only remaining waste besides the sanitary sewage.

Full-Load Operations

The formaldehyde concentration in the raw waste varied from 800 to 1,500 p.p.m., averaging about 1,300 p.p.m. The average value going to the filter was about 200 p.p.m., that leaving the filter was about 167. The filter efficiency was low, averaging 16.5 per cent. However, the over-all system efficiency was fairly good, averaging about 76 per cent. No reduction took place in the lagoon until the following spring.

The average flow to the plant was about 40,000 g.p.d. However, due to some poor joints in the main trunk line, this volume increased considerably during times of rainy weather.

The average filter removal of formaldehyde was about 355 lb. per day, equivalent to 1.47 lb. per cu. yd. or 2,500 lb. per acre-ft.

B.O.D. in the raw waste varied from 1,400 to 3,100 p.p.m., averaging about 2,500 p.p.m. Filter influent B.O.D. averaged about 400 p.p.m. and effluent values about 340 p.p.m., a reduction of 60 p.p.m. This was equivalent to 2.68 lb. per cu. yd., or 4,530 lb. per acre-ft.

Winter Experience

With the advent of cold weather concern was felt about the efficiency of the treatment plant and the possibility of a freeze-up, especially in the lagoon. The raw waste waters entering the plant averaged about 85° F. When the air temperature dropped to about freezing, the circulating water in the system dropped to about 60° F. It was believed that a temperature of at least 65° F. was desirable. Condensate from the unit heaters in the pump house was arranged to discharge into the wet well, thus bringing the circulating water to about 66° F. With air temperatures down around 10° F. the circulating water probably would drop to 35° F., which would be entirely too low. To overcome this condition steam was bled into the system through a thermostatically controlled valve set at 60° F. Except for those periods when there was insufficient steam available, the liquid temperatures were held very close to this value. The only trouble from icing occurred around the inside of the filter tank, and required breaking out only a few times during the whole winter.

The lagoon remained open nearly the whole time. Only when the outside temperature dropped to 0° F. did a light skim of ice form, and this only lasted for two days.

Ponding Troubles

In late January it was noticed that the growth on the filter stone began to increase in thickness; after about two weeks serious ponding developed. The color of the slimes changed to an orange yellow. Formaldehyde determinations indicated very little change in concentration. However, B.O.D. going to the filter rose sharply to over 4,000 p.p.m. Effluent values rose above 3,500 p.p.m. This was indicative of serious contamination of the waste waters, and a thorough study was made to determine the source. It was found that one of the process storage tanks had developed a leak and was draining into a floor trench, which discharged into the lift station sump. This leakage contained a high percentage of sodium formate and the B.O.D. was approximately 20,000 p.p.m. Another source was from some leaky catch pans, which allowed pentaerythritol liquor to run on the floor and into the main floor drain at intervals. Several days were required to find these leaks. The catch pans were easily fixed, but several weeks were required to permanently repair the storage tank.

During this period of excessive overload there was no unusual sloughing of the bacterial growth. Past experience had indicated that sodium formate was very toxic. Determinations on spot samples of the waste applied to the filter indicated that there were concentrations of this material as high as 5,000 p.p.m. Heretofore it had been believed that toxicity was only relative and that in time acclimatization could be developed for most any material. Time was the factor. In this particular case there was what was believed to be a very toxic material, yet the biological growth had survived and actually increased in volume. The nitrogen balance was completely upset, as the rate of feed of aqueous ammonia was still regulated by the pH requirement and the diammonium phosphate was added on the basis

of carbon in the formaldehyde and resin plant wastes. It was finally concluded that the toxicity of the formate was completely nullified, due to the excessive amount of organic matter provided by the pentaerythritol.

During this period formaldehyde removals actually increased. There was little change in the raw waste concentration and the applied solution ranged from 200 to 225 p.p.m. Filter effluent values dropped to 135 to 150 p.p.m., providing efficiencies of 30 to 35 per cent and over-all efficiencies of 85 per cent.

Meanwhile, an attempt was made to wash off the heavy growths by stopping the distributor and flushing down a section at a time. This proved futile, as the ponding was only slightly reduced and came back completely the next day. The heavy growth prevented ventilation up through the filter. It was felt that some further attempt should be made to end the ponding, so a step was taken which would be looked upon with horror by any good operator or engineer. A fire hose was used, the full force of the jet being turned on the stones until the whole filter area had been worked over. This procedure required over half a day and about half filled the sedimentation basin with sludge, which was pumped out and hauled away to the sludge disposal area.

The filter was put back in service and no further ponding developed. After a day formaldehyde removals returned to normal. The B.O.D. values remained high for about a week, until the leakage into the system was eliminated, then gradually returned to about normal. Growth developed on the stones near the surface just as it had previously.

Although this procedure is not recommended, it was an expedient method in solving the temporary problem and did not seriously affect the filter.

Operational and Equipment Changes

In late spring several changes were made in process operations. These had a direct bearing on waste plant operation. One change resulted in elimination of resin wastes requiring treatment. Thus, aside from the sanitary sewage, the whole load at the waste plant was formaldehyde. Other alterations resulted in intermittent discharge of formaldehyde with very little discharged during the third shift, thus producing very wide fluctuations in filter loading. Although the average concentration dropped to about 500 p.p.m. in the raw waste, the fact that there were extensive periods when there was none entering the system produced considerable shock and resulted in heavy sloughing of the filter. To overcome this trouble equalization of the incoming waste was necessary.

Studies of the operating cycles indicated that the installation of a 6,000-gal. tank, together was a 40-g.p.m. pump, would solve the problem. This was installed ahead of the waste plant, and the equalized liquor then discharged into the main wet well. The tank was provided with an inlet distributor, scum drawoff, and baffled overflow. To make this operation most effective, a bleed line was installed so that a small amount of the waste prior to overflow into the effluent trough was recirculated back into the pump suction well. The rate of recycle was controlled by a butterfly valve so set that as the volume of flow into the system increased the amount recycled would be reduced and finally shut off. This arrangement provided initial dilution and more effective equalization. Figure 2 shows the treatment plant with this new equipment.

The new installation was not completed until July, due to delays in securing equipment. During this interval the plant was operated as originally designed. Filter sloughing seemed to be heaviest in the morning, gradually reducing to a small amount by noon. This resulted from low discharge during the night and the attendant high shock load during the first few hours

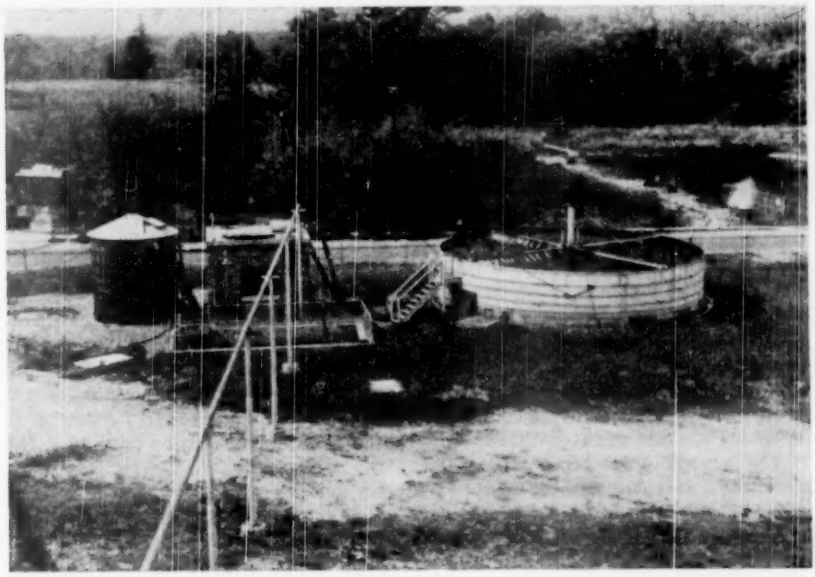


FIGURE 2.—Formaldehyde wastes treatment plant after addition of equalization tank.

of the day shift. By late morning the system had adjusted itself to the new conditions. Over-all operating results fluctuated with the filter removals.

With an influent concentration of about 500 p.p.m. formaldehyde, the system concentration would be up to 350 p.p.m. during the morning, with 10 to 15 p.p.m. reduction through the filter. By afternoon the system concentration was down to 200 p.p.m. and reductions up to 30 to 40 p.p.m. (20 per cent) were obtained through the filter. System efficiencies would rise to 67 per cent.

The lagoon was the stabilizer of the system. With warm weather and sunlight 50 per cent reductions were obtained, so that the over-all picture was not too bad, averaging about 84 per cent total removal.

With the installation of the compositing tank, the treatment plant began to function properly. The heavy sloughing ended; normal unloading took its place. System concentrations began to hold in the range of 100 to 150 p.p.m., and filter reductions increased to about 50 p.p.m. (33 per cent). System efficiencies rose to 80 per cent, with the lagoon removals increasing this to 90 per cent. B.O.D. dropped to 200 p.p.m. in the waste to the lagoon, and to 100 p.p.m. in the lagoon effluent. As the hotter summer weather continued the lagoon efficiencies rose to about 75 per cent. Formaldehyde concentrations in the effluent dropped to about 25 p.p.m. and B.O.D. to about 50 p.p.m. The over-all system efficiency rose to about 95 per cent.

Further Process Changes

During the summer several changes in operations again affected the operation of the waste plant. The changes eliminated the severe intermittent discharges, but resulted in increased concentrations of formaldehyde. The average composite, previously around 500 p.p.m., increased to from 2,000 to 6,000 p.p.m., averaging about 3,400 p.p.m. This upset the treatment plant for about a week. Concentrations increased to about 1,000 p.p.m. in the eir-

culating system and severe sloughing took place. Gradually the system stabilized itself and filter influent values dropped to about 300 p.p.m. Filter efficiencies increased to 23 per cent, providing about 70 p.p.m. reduction; system efficiencies rose to 92 per cent. The lagoon provided about 96 per cent reduction, making the over-all efficiency 99 per cent. The average concentration of formaldehyde from the lagoon averaged 20 p.p.m. Installation of the equalizing tank is believed to be responsible for the efficient functioning of the system. Comparable results were obtained until early October, when lagoon efficiencies have dropped off due to colder weather and reduced sunlight.

The growth developed on the filter from the formaldehyde has the appearance of an icy coating with a slight grayish cast. Aside from the grayish cast, it is identical with that developed on the pilot plant unit.

General Data and Problems

In the use of aqueous ammonia for pH correction, the amount necessary to hold the pH at 7.0± in the system has been about 22 lb. of NH_3 per day. On the basis of carbon in the raw waste this has provided a carbon-nitrogen ratio of about 9 to 1. Diammonium phosphate has been added to provide 0.017 p.p.m. phosphorus per p.p.m. carbon, equivalent to approximately 0.0025 p.p.m. per p.p.m. B.O.D. The total nitrogen added by the two sources has held the carbon-nitrogen ratio in the neighborhood of 10 to 1.

A peculiar condition has been noticed in the system's operation on formaldehyde. When the pH is maintained at 7.8 and above, there is considerable sloughing and very little settleability, the whole system becoming quite turbid. This condition persists until the pH reaches 5.5, at which point the whole system clears up and the water takes on a greenish blue color. The pH can then be raised to 7.2 without any change in character of the circulated water, irrespective of normal variation in formaldehyde concentration.

The sludge problem has not yet been solved completely. Early in the operation anaerobic decomposition was tried, but was unsatisfactory. This followed similar results in another plant. The negative result was due to the small quantity of rosin oils, which coated the sludge particles.

With the plant handling only formaldehyde wastes, anaerobic digestion tests were made again. This time digestion was accomplished. Although only one test has been made so far, further work is contemplated as time permits. The test was made on 240 g. of basin sludge taken from the bottom of the sludge receiving well. The digestion temperature was 90° F. After three days, gas was evolved, more than 98 cc. being generated in about 12 hr. It is believed that the possibilities arising from such a method of decomposition can lead to development of means for such decomposition of the raw liquor.

The sludge problem, as such, has not been very troublesome. There has been some tendency toward stoppage in the settling basin sludge pockets. However, the use of a probe during sludge withdrawal is all that has been necessary to keep them open. Sludge volumes from straight formaldehyde wastes operation average about 0.11 lb. dry solids per lb. formaldehyde. This is equivalent to about 0.06 lb. per lb. B.O.D.

During the year's operation flies were noticed only once. These were not a true psychoda, but were a small black fly about $\frac{1}{8}$-in. long. They seemed to come up out of the filter only along the sides. When the end nozzles on the distributor were adjusted to provide some washing action on the stones, the fly problem vanished for good.

Plant Operating Control

The treatment plant was designed to be as automatic in operation as possible, in order to reduce operating labor to a minimum. General mechanical operation is under the supervision of the power department; chemical control and analytical work is handled in the plant laboratory under the supervision of the chief chemist.

In general, the plant requires the services of one man an average of 2 hr. per day. This includes drawing sludge from the basin, skimming the basins, filling chemical tanks, and taking samples. Included in this is the semi-weekly pumping of the sludge from the main wet well into the tank truck and hauling to the plant sludge lagoon.

Due to limited manpower in the laboratory, the many and detailed analyses so necessary for a complete evaluation of plant operations and for a comprehensive report have not been made. Much of the time control has been based only on pH and formaldehyde analyses, as these were easily and quickly made and indicative of operation. Analyses will be made in the future to allow development of a better picture of the plant.

Conclusions

In looking back over the first year of full-scale operation, the major conclusions reached in early pilot plant experiences still hold. These were that:

1. The high-rate trickling filter can be used for treatment of formaldehyde, organic oils, and organic acids, and will provide satisfactory reduction. Removals per cubic yard of medium under full-scale operations have decreased somewhat from pilot experiences. Removals obtained were as follows:

Formaldehyde Concentration (p.p.m.)	Removal (lb./cu.yd.)	Removal Efficiency (%)
110	1.12	23
184	1.25	16
266	1.75	15
300	3.10	23
360	3.45	28

2. It is not necessary to maintain the pH constant at 7.0, as variations as low as 4.5 and as high as 8.5 will not affect operation. However, it is necessary to hold a fairly uniform pH wherever it may be.

In full-scale operation it is necessary to hold the pH at about 7.0 if low turbidity and B.O.D. values are to be maintained in the system. Where a lagoon follows the filter system this is not important.

3. Short sedimentation periods are effective for the filter system.

4. There is no filter fly problem with wastes of this type.

Finally, the full-scale plant based on pilot plant studies has effectively treated the plant wastes, regardless of their wide variation, and produced a satisfactory effluent.

Acknowledgment

Grateful acknowledgment is due the members of the Division of Sanitary Engineering and the Lawrence Experiment Station of the Massachusetts Department of Health for their splendid cooperation and valued assistance in planning and carrying out this work.

References

1. Dickerson, B. W., "A High-Rate Trickling Filter Pilot Plant for Certain Chemical Wastes." THIS JOURNAL, **21**, 4, 685 (July, 1949).
2. "Standard Methods for the Examination of Water and Sewage," 9th Edition, p. 140. American Public Health Assn. (1946).

DISCUSSION

By H. Heukelekian

Research Engineer, Department of Sanitation, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.

Mr. Dickerson's paper is of interest for several reasons of general and specific nature.

In the first place, it illustrates once again the value of careful laboratory and pilot plant research in the development of methods of treating industrial wastes for which no preceding experience is available. The work reported in this paper is based on one year's operating experiences of the actual plant installation following the results obtained from pilot plant experiments reported in the July, 1949, issue of This Journal. The time and money spent on pilot work are amply rewarded, because without such experience it would have been foolhardy to proceed with the design and construction of the actual plant. In this instance, as well as in other similar situations, the experience obtained from the pilot plant has not only been invaluable, but also has come very close to the performance of the actual large-scale units.

Secondly, the general impression created by the paper is that an almost impossible task has been performed. Consider the stringent stream requirements and consequent necessity of reducing a 2,000-lb. per day B.O.D. load to 30 lb. allowable loading on the stream—a formidable task indeed, even if the wastes were innocuous and non-toxic like sewage or industrial wastes containing readily available organic matter ordinarily encountered. Instead, the wastes contained large quantities of formaldehyde, which is used ordinarily for disinfecting purposes, with additional amounts of rosin oils, phenols, organic acids, and pentaerythritol thrown in for good measure. The waste is not only acid in nature, but also contains materials that microorganisms do not generally relish as food. In addition, it is deficient in proper inorganic nutrients. Thus, the waste had to be neutralized, nutrients had to be added, and the liquid had to be almost spoon fed before it could be successfully treated by biological methods. Despite these difficulties the attempt was made and success was obtained by the careful application of certain principles.

The third item is that the first and most important step taken was the survey of the possibilities of reducing the quantity of waste. Mr. Dickerson's success in this respect illustrates once again what can be accomplished by elimination of waste. Consider the decrease of formaldehyde load from 1,800 lb. to 300 lb. per day, and B.O.D. load from 2,000 lb. to 675 lb. per day, and the decrease in total flow from 500,000 to 40,000 g.p.d. Although the author does not mention whether the recovery of some of these products formerly discharged to the sewer resulted in economic benefits, it is certain that it reduced the cost of treatment.

A fourth interesting lesson that can be learned from this paper is that, although normal sewage treatment processes are the basis for the treatment of many industrial wastes, a selection cannot be made arbitrarily but has to be made carefully in respect to the suitability of the type of treatment for the particular waste. Consider, for instance, the unsuitability of treating these wastes by digestion. It follows that anaerobic digestion with its methane fermentation phase is more sensitive to certain toxic wastes than are oxidation devices.

What at first glance seems to be even

more surprising is the fact that a low-rate filter was not suitable, whereas the high-rate filter performed well. The explanation offered by Mr. Dickerson is that the formation of insoluble compounds (tanning agents) causes the death of the bacteria by cutting them off from their food supply. In the low-rate filter these compounds accumulate and intermittently slough off, whereas in the high-rate filter the accumulation is greatly reduced because of continuous sloughing. Whatever the merits of this speculation there are other possible explanations. It is true that the load is greater on high-rate filters than on low-rate filters; but the concentration of formaldehyde is lower by virtue of recirculation. Note the necessity of high recirculation ratios (40 to 1).

More specific comments and remarks are as follows:

1. Mr. Dickerson stated that sodium formate is more toxic than formaldehyde without presenting any evidence. It is difficult to reconcile this with the statement made that during the period when a process storage tank was discharging a very high percentage of sodium formate, because of a leak, biological growth survived and actually increased in volume and formaldehyde removals by the filter actually increased. If sodium formate is not as toxic as it was originally believed to be, the continued practice of neutralization with ammonia rather than sodium hydroxide to prevent the formation of sodium formate is not necessary. This is a minor plant. Whether sodium formate is toxic or not ammonia may be a more suitable neutralizing agent than sodium hydroxide, because it serves the dual purpose of furnishing nitrogen as well as being a neutralizing agent. The important question, from a rather academic standpoint, is whether sodium formate is actually more toxic than formaldehyde. Results presented by Sawyer and Hermann (1) indicate that sodium formate begins to exert an inhibiting effect on B.O.D. at 10 p.p.m., whereas formaldehyde is not toxic up to 21 p.p.m. We have discovered no lasting inhibiting effect by formaldehyde up to 185 p.p.m. concentration, which gave an initial inhibition of oxidation for two days followed by recovery on the third day. It is probable that with adaptation this concentration could be tolerated without even an initial inhibition. It is also of passing interest that a B.O.D.-formaldehyde ratio of 2:1 is obtained by Mr. Dickerson although Sawyer (1) and the writer have obtained B.O.D.-formaldehyde ratios more in the order of 1:1.

2. Mr. Dickerson stated, also, that every method of chemical treatment to provide destruction of formaldehyde was tried, but was found unsatisfactory. Each was either uneconomical or the end product was more difficult to handle than the original material. The question is raised as to whether the treatment of formaldehyde, with ammonia (with the formation of hexamethylene tetramine) was tried, or whether in the treatment of the waste with ammonia for neutralization an additional advantage is not obtained by the formation of this compound. Some of our experiments have shown that hexamethylene tetramine up to 2,000 p.p.m. concentration is subject to biological oxidation without any inhibiting effect.

3. The wisdom of omission of an equalization tank in this, as well as any other type of industrial waste treatment process, is questioned. Events necessitated subsequent addition of an equalization tank.

4. The question arises as to the basis of selection of filter stones 3 to 5 in. in size. It is possible that a somewhat smaller size stone might have given a higher efficiency. It does not seem that serious clogging was encountered, with the exception of the period when sodium formate was leaking into the waste.

5. In assessing the performance of the filter in removing formaldehyde, or even B.O.D., it seems better to base it on the concentration of these ingredients in the waste before mixing with the recirculated effluent, rather than on the basis of quantities applied to the filter after recirculation. Recirculation is an integral part of the treatment and the concentration of formaldehyde in the recirculated effluent should be disregarded. There must be some reduction of formaldehyde through the filter. Otherwise, the process would not be effective. The important item is that starting with say 800 p.p.m. formaldehyde in the waste, by recirculation and filtration the effluent from the filter had only 167 p.p.m., irrespective of the fact that the applied mixture had a formaldehyde content of 200 p.p.m., the major part of which came from recirculation.

6. It is stated that formaldehyde removal by the filter was 355 lb. per day, whereas in an earlier section, dealing with the quantities of waste produced, it was stated that the total load of formaldehyde produced at the plant was reduced to a maximum of 300 lb. per day.

7. If pH values as low as 4.5 do not affect the operation, as stated in the summary, what is the reason for adjusting the pH of the waste to 8.0?

8. The author is to be commended for the measures he has taken to maintain the efficiency of the filter during the winter by the introduction of condensate from unit heaters and for bleeding steam into the waste to overcome the cooling effect when using high recirculation ratios. This is a phenomenon that exists in other high-rate trickling filter plants.

9. It is of interest to note that formaldehyde removal efficiency of the filter is not reduced, but is actually a little higher with the higher applied concentrations of formaldehyde.

10. Finally, it would be of interest to know what method was used for the determination of formaldehyde in the waste, and the accuracy of the method.

Reference

1. Sawyer, C. N., and Hermann, E. R., "Effect of Toxic Substances on Biochemical Oxygen Demand." Paper presented at a meeting of Amer. Chem. Soc., Atlantic City, N. J. (Sept., 1949).

INDUSTRIAL WASTES DISPOSAL AT PITTSBURGH *

By John F. Laboon

Chairman, Allegheny County Sanitary Authority, Pittsburgh, Pa.

Little had been accomplished in the treatment of industrial wastes in the Pittsburgh area in the past. In the absence of municipal sewage treatment plants in this industrial area, industry could not be expected to go all out on a treatment program; but now that the municipalities have developed a program for collection and treatment of municipal wastes, industry is not far behind.

The first legislation applying explicitly to industrial wastes and their control was passed in 1937. Acid mine drainage and silt were exempted until in the opinion of the Pennsylvania Sanitary Water Board "practical means for the removal of the polluting properties of such drainage shall become known." This act was amended in 1945 to put mine silt under the law, but provided for diversion of acid mine drainage at State expense and exempted such industrial wastes as are discharged "into any municipal sewer system."

Industrial Waste Installations

Several industries have constructed treatment plants in the Pittsburgh area in recent years in compliance with the orders of the State Sanitary Water Board. The United States Steel Corporation built two treatment plants at the new Irvin works 10 years or more ago. One treatment plant handles plant sewage and the other pickle liquor wastes. The pickling wastes are neutralized with slaked pebble lime. The slurry is agitated by air and the entire contents of the neutralizing tanks are pumped into tank cars for disposal in a lagoon located in the center of a hot slag dump. This plant may soon be replaced by a recovery process.

More recently, a large glass works installed multiple tray thickeners for removal of solids, which formerly discharged through the plant sewer to form a large bar in the Allegheny river. The solids are pumped to a lagoon located in the hills above the plant. A local chemical plant installed gravitational separation with aeration and partial evaporation for removal of tastes and odors due to resinal wastes. A large oil company installed separators for removal of oil wastes. One of the largest and most modern coal mines in the world installed thickeners, Diester tables, and filtration for treatment of bituminous coal washing wastes.

Some of the packing plants have grease traps, which serve also to catch some of the larger solids. Nevertheless, even in these cases, tests indicate that much of the grease and solids escape to the streams.

The Problem

The discharge of 3,000 tons of untreated acid mine wastes daily into the streams of this area has been a deterrent to the establishment of sewage treatment in many ways. Although making it possible to keep down unbearable putrefactive conditions in the rivers by its action on organic pollution, acid mine waste has done great damage to structures located in the streams and also has made the use of streams for recreation, navigation, in-

* Presented at 22nd Annual Meeting, Federation of Sewage Works Associations; Boston, Mass.; October 17-20, 1949.

dustrial purposes, and as a source of public water supply either undesirable or costly. Acid mine drainage, therefore, can be said to be the greatest and most damaging industrial waste discharged without treatment into the streams of this area.

The Pittsburgh area is noted primarily for its coal and steel industries. Therefore, the major part of its industrial wastes must come from these sources. However, in addition to iron and steel and coal industries, there are located also in this area many other important industries, including the H. J. Heinz Company, one of the largest food preparation plants in the world; Westinghouse Electric Corporation; Westinghouse Airbrake Company; Aluminum Company of America; American Cyanamid & Chemical Corporation; American Window Glass Company; Cruikshank Bros. (food); Lutz & Schramm, Inc. (food); Falk & Company (oils and resins); and the Vanadium Corporation. In addition, there are copper mills, galvanizing plants, paint manufacturers, at least 6 breweries, a distillery, wool scouring works, dairy plants, stock yards (forming the chief off-car rest point for cattle between Chicago and New York), various chemical manufacturing plants, cement mills, oil refineries, packing plants, and many commercial establishments manufacturing various goods and adding to the industrial waste problem.

In 1945 and 1946 almost 100 industries and more than 100 municipalities located in the Pittsburgh area were ordered by the State Sanitary Water Board to abate pollution of the streams. A great many more industries were contributing to the pollution of the streams in violation of the law, but according to the 1945 amendment of the Pure Streams Act (Pennsylvania) those industries which were connected to public sewer systems were exempt from direct action of the State and the responsibility for the discharge of polluting wastes of industry in such cases rested on the shoulders of the municipality whose sewer system was being used for that purpose.

Wastes Surveys

Of this group of industries, 36 agreed to have the Sanitary Authority make a study and analysis to determine whether their wastes were acceptable to the Authority for treatment in conjunction with municipal wastes, and under what conditions, if any. A nominal charge was made for this service. When it was established as a matter of policy that pickle liquor wastes could not be accepted by the Authority, six of the industrial studies were rejected, leaving 30 for final study and determination.

The 30 industries studied in detail represented a total annual flow of more than 3,500 m.g., with weighted suspended solids content of 458 p.p.m. and B.O.D. of 682 p.p.m. One chemical plant alone contributes almost one-third of the total annual B.O.D. of this group of industries. The highest concentrations of suspended solids and B.O.D. come from a distillery. The next highest come from a wool scouring plant. The total of the 30 industries represented a yearly equivalent population of 330,000 (based on 0.167 lb. of 5-day B.O.D. per capita daily).

The findings of this study, taken in conjunction with the chemical analyses of the weirings of 32 important municipal sewer outfalls scattered throughout Allegheny County, formed the basis for determination of a weighted value for suspended solids and B.O.D. as representative of the sewage to be expected at the central treatment plant proposed for the whole of Allegheny County and 100 of its municipalities affected by the study. The weighted result was a suspended solids content of 275 p.p.m. and a B.O.D. of 300 p.p.m. The total quantity of industrial wastes was estimated to be 30 m.g.d for the year 1965, or 17 per cent

of the total dry weather flow to the plant. Commercial wastes would total about 20 per cent of the calculated 1965 dry weather flow. The equivalent population represented by acceptable industrial wastes, as estimated for the year 1965, is 910,000 (based on 0.167 lb. of 5-day B.O.D. per capita daily), or 53 per cent of the expected 1965 population.

In several instances, it was found that substantial losses were being suffered by industry due to the wastage of water or to the discharge of valuable recoverable wastes into the sewers. The wastage of water was doubly costly because sewage service charges will be based on water usage. A packing plant without grease traps or screens was losing almost 7 tons of grease daily. Three other plants with grease traps were losing a total of 5,000 lb. of grease daily. In some cases industry has already initiated plans for recovery and salvage. The $15,000,000 extension now being made to the H. J. Heinz Co. plant would not have been possible if the Sanitary Authority survey had developed that the wastes of the present plant could not be accepted, thus requiring the use of the available ground for a separate industrial waste treatment plant.

Policy on Waste Acceptance

The studies of the industrial plants served to establish policies of treatment as well as the charges which the Authority would make with respect to treatment of industrial wastes. It was concluded that all industrial wastes originating in the service area would be acceptable for treatment excepting pickle liquor wastes and acid mine drainage. Limitations established with respect to other toxic and deleterious wastes have already been published (1).

Pretreatment was specified in several instances where unusual conditions warranted. Furthermore, complete control over the discharge of industrial and commercial wastes into public sewer systems is made available to the Authority by the long-term agreements now being executed between the Authority and the municipalities for sewage service.

A definite position has been taken with respect to acceptance and treatment of industrial and commercial wastes. The Authority proposes to accept for treatment all wastes that will not affect either structures or treatment processes of the Authority, taking advantage of the diluting properties and neutralizing effects of large quantities of municipal sewage on industrial wastes to be treated. However, as pointed out by Danse (2),

> "It is manifestly impossible that any large municipal sewage or drainage system could be constructed so as to take any and all industrial wastes. Many industrial wastes are of such nature that they would be deleterious to the materials of construction commonly used in sewers, or they would be hazardous as regards toxicity to those adjacent to the sewer structures; hazardous because of possible explosion damage in or near the sewer structures, a nuisance from the standpoint of noxious odors, or definitely disturbing or deadly to the activity of the sewage treatment processes. Accordingly, industry will understand that wastes which are deleterious or noxious should be pretreated before discharge into public sewer systems."

Basis of Charges

The Authority proposes to add a premium to the proposed regular sewage charge for treatment of industrial and commercial wastes in conjunction with sewage where such wastes are excessively concentrated or where they possess certain qualities which require more than ordinary treatment. The premium is based on the following conditions:

1. Suspended solids in excess of 275 p.p.m.
2. B.O.D. in excess of 300 p.p.m.
3. Chlorine demand in excess of average.

4. pH and color if future conditions justify.

Suspended Solids and B.O.D. Charge

For the present, it is proposed to charge for excessive suspended solids and B.O.D. in accordance with the formula

$$F = 1 + R\left[\frac{0.75(S_1 - S_a)}{S_a} + \frac{0.25(B_1 - B_a)}{B_a}\right]$$

in which F is the factor to be applied to the basic rate, R is the ratio of quality cost to total annual cost ($= 0.15$), S_1 is the p.p.m. of solids in the sewage from the particular industry, S_a is the average suspended solids of all sewage ($= 275$ p.p.m.), B_1 is the p.p.m. of B.O.D. of the sewage from the particular industry, and B_a is the average B.O.D. of all sewage ($= 300$ p.p.m.). The increase in cost on this basis is predicated on the actual treatment costs of the excessive volumes, suspended solids, and B.O.D. The charge is nominal. As an example, on the basis of a suspended solids content of 500 p.p.m. and a B.O.D. of 500 p.p.m., the additional charge would be 11.7 per cent of the quantity billing.

Chlorine Demand Charge

An additional charge will also be made for treatment of wastes possessing an excessive chlorine demand. Chlorination of the effluent of the sewage treatment plant will be a requirement of the Sanitary Water Board. The chlorine demand of the central sewage plant cannot be determined until the plant is in operation; therefore, only the rate formula can be given now, as follows:

$$R_c = F\,P_c\,(C_1 - C_a)$$

in which R_c is the surcharge rate for chlorine demand, in cents per 1,000 gal.; C_1 is the chlorine demand of wastes from the particular industry, in p.p.m.; C_a is the average chlorine demand of all sewage, in p.p.m.; F is a factor for converting p.p.m. to pounds per 1,000 gal. ($= 0.00835$); and P_c is the purchase price of chlorine, in cents per pound.

Steel and Mine Wastes

As pickle liquor wastes are not acceptable to the Authority, these wastes must be treated separately by industry. Neutralization is the most common form of treatment of such wastes, but the disposal of the resulting slurry or sludge is still a difficult problem, especially where space for lagoons is not available. Progress, however, is being made in another direction. The Iron and Steel Institute has supported research in this field during the past several years at the Mellon Institute. Recent work by means of pilot plants promises interesting results in the matter of dewatering of the neutralized slurry, which until now has been difficult and uncertain.

Research is also at work on acid mine drainage. The State (Pennsylvania) is in the process of establishing tolerances with respect to the discharge of rinse waters into streams in terms of acid and iron. The State Sanitary Water Board has established research at the Mellon Institute for study of the effects of acid mine drainage on streams, and the conditions under which formation of acid occurs in mines. Another State project at the Mellon Institute is engaged in the study of treatment of acid mine drainage. In addition, Bituminous Coal Research, Inc., Morgantown, W. Va., is also engaged in research with respect to the general subject of acid mine drainage, and the U. S. Bureau of Mines is engaged in a search for methods of quick analyses of these same wastes.

Stream clean-up in the Pittsburgh area is on the move at every front. The Pittsburgh project, which now includes 59 municipalities, will cost $55,-

000,000 at present prices. Other municipalities in the county will also spend large sums for pollution abatement. With the cooperation of industry and with the backing of important civic interests, pollution abatement in Allegheny County will be a fact in the not too distant future.

References

1. Laboon, J. F., "Sewage Disposal Program of the Allegheny County Sanitary Authority." THIS JOURNAL, **21**, 2, 197 (Mar., 1949).
2. Danse, L. A., "Regulation of Industrial Usage of Municipal Sewers (Discussion)." THIS JOURNAL, **19**, 5, 815 (Sept., 1947).

DISCUSSION

By Hayse H. Black

Chief, Industrial Wastes Section, Environmental Health Center, U. S. Public Health Service, Cincinnati, Ohio

This paper may well be considered a sequel to the author's earlier work, to which he refers. The Allegheny County Sanitary Authority's program contemplates a central treatment works located on the Ohio River, immediately upstream from McKees Rocks Bridge. Plain sedimentation preceded by aeration is calculated to remove 40 per cent of the organic pollution load as measured by B.O.D. Chlorination is provided for periods of critically low stream flow.

The Sanitary Authority has adopted the policy of accepting all industrial wastes which are amenable to treatment, provided they will in no way damage the sewerage system or interfere with its normal functions. In fact, spent pickle liquor and acid mine drainage are the only exceptions cited. Limitations imposed for toxic and deleterious wastes in the composite sewage, as received at the treatment works, take into consideration their effect on treatment and on the receiving stream. This liberal policy in highly industrialized Pittsburgh should prove especially attractive to manufacturing interests.

Credit is due those Pittsburgh industries which have already installed separate waste treatment works. Some industries may elect to provide partial treatment and temporary storage for equalizing flow. Still others will be served entirely by the Sanitary Authority's sewerage system. Design of the collecting system and central treatment works has been based on full knowledge of present industrial requirements, with liberal capacity for anticipated future demands.

The surcharge formulated for industrial and commercial wastes is a contribution to equitable financing of combined waste treatment. This system provides an incentive for industry to reduce wastes to an absolute minimum. It invites attention to concentrated wastes in a manner readily comprehended. The routine waste checks required constitute an operation record invaluable to industrial management.

In considering industrial wastes, acknowledgment is due industry for prosecuting an active and constructive program. Major contributions are being made in the field of industrial waste treatment by trade associations and their technical committees. Several major industries employ full-time sanitary engineers and chemists, whose duties include the study of proposed new plant sites, with particular reference to water supply and waste disposal. Collection and treatment of process wastes are integrated with development. In fact, it is not uncom-

mon for new processes to be influenced in their early stages of development by waste disposal.

Examining the other side of the ledger, it is prudent to take inventory of unsolved trade waste problems, of which there are many. Much remains to be learned about some trade wastes which have long been bothersome. For example, there is a dearth of authentic information on the factors influencing the characteristics of some of the most objectionable industrial wastes. New processes and the manufacture of new products continue to be a threat to the receiving stream.

The splendid response displayed by Pittsburgh industries to Ohio River pollution abatement is typical. Industry has indicated a willingness to accept industrial waste treatment as another competitive process. The active cooperation of industry in providing facilities for recovery from or treatment of industrial wastes constitutes an admirable response to the public demand for clean streams. Considering remaining unsolved industrial waste problems, it is reasonable to expect that active research will develop recovery or treatment processes which are economically feasible. Coincident with this continued research, it is incumbent on organizations administering anti-stream-pollution laws to become familiar with the intricacies of industrial waste problems.

In closing, it would seem fitting to acknowledge the vast amount of work on the part of prominent individuals and well-known agencies which has preceded this development. Consummation of this construction program and inauguration of effective operation will stand as a monument to all who have participated. Downstream interests on the Ohio River are entitled to the long-sought relief anticipated from scientific and vigilant operation of waste treatment facilities being provided for the Pittsburgh area. The work of the Allegheny County Sanitary Authority has just begun.

INDUSTRIAL HYGIENE AND SAFETY COURSE

An in-service training course in Industrial Hygiene and Human Relations for Safety Personnel is being offered by the School of Public Health, University of Michigan, on June 19, 20, and 21, 1950, at Ann Arbor, Mich. This is the thirty-fifth in a series of in-service, non-credit, training courses offered by the University's School of Public Health, and the second on industrial hygiene for safety personnel. It is, however, the first to feature human relations in connection with accident prevention.

At the request of those engaged in safety work, emphasis will be placed on practical recognition, rather than correction, of health and hazard exposures.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

PASS THAT EXPERIENCE ON

Sage advice on many aspects of sewage treatment, gleaned from some 40 years' experience in the field, was contained in an address by J. H. Garner before the 1949 Summer Conference of the Institute of Sewage Purification. Choosing as his subject "Fents and Fancies" (remnants and whims), he reminisced not only on several technical problems and solutions of his long tenure as chief inspector of the West Riding of Yorkshire Rivers Board, but also digressed, with his famous wit and wisdom, on some of the philosophical aspects of sewage treatment and stream pollution abatement.

In speaking of his conception of the ideal sewage works manager, Mr. Garner said:

> "What I like to see in a sewage works manager is a man really on top of his job. He should regard his job as a public trust and his responsibilities to the public as of great importance. This attitude invariably makes for good maintenance, efficiency, and a loyal and contented staff. . . .
>
> I picture this ideal manager, leaning back in his office armchair, with ample time to read and write, his jacket off and shirtsleeves rolled up, smoking a cigar paid for out of his own salary, with a beaker of iced lager at his elbow and occasionally chuckling to himself 'Every day a Sunday.'"

Of particular interest is the phrase "with time to read *and write*," indicating a recognition of the fact that technical contact with others, giving as well as receiving, is necessary to professional growth. Often, the value to be gained from an experience is lost, not only to the profession but even to the individual directly concerned, because of a shrug-of-the-shoulders attitude about setting it down in black and white.

Those who only read, and never write, would do well to reflect on the thought that if everyone took that attitude there would be nothing to read, particularly in such a medium of exchange for operational matters as is The Corner. As has been pointed out many times in the past, this department of the JOURNAL requires broad and continuous participation—in the form of material—on the part of plant superintendents and operators in order to fulfill its purpose.

The Corner is really a market place for operation personnel in plants of all sizes and types to exchange their trials, tribulations, and troubles for solutions, solace, and salvation. However, like a market place, it cannot operate if merchandise is always removed and none is brought in.

Look around; dig into those diaries, those reports, and the storage spaces of memory. Hundreds of the kind of items we are seeking and you like to read are lying buried there. Pass them along so others can benefit by them. Letters, clippings, or even marked operating reports are just as welcome as formal manuscripts.

H. P. O.

GAS ENGINE EXPERIENCE AT BUTLER, PA.*

By T. R. Haseltine

Partner, The Chester Engineers, Pittsburgh, Pa.

The design of the Butler, Pa., facilities for gas collection, storage, and utilization was made in 1938, at which time the writer was superintendent of sewage treatment for the City of Butler. In that capacity he checked the design, suggested certain changes, and eventually passed on it. Therefore, equal responsibility with the designer is claimed for any good or bad points in that design. At the time, no data were available on gas production because the old digesters were not equipped for gas collection. The design selected was one that was intended to utilize practically all of the sludge gas that would be produced and depended on the purchase of auxiliary natural gas during periods of low gas production.

The auxiliary fuel was obtained from two privately owned gas wells. For all practical purposes, that source failed during the winter of 1944–45, and since then the need for certain changes in the design of gas storage and utilization facilities at Butler has become increasingly apparent. Nevertheless, the engine generator still proves to be a worthwhile investment. As shown in detail by Table I, the annual saving, prior to failure of the auxiliary fuel supply, was estimated to be about $1,874; after the failure, the saving was about $312 a year less, but still very much worthwhile. The equipment probably paid for itself in about 7 years.

Equipment Limitations

However, there are certain lessons to be learned from the Butler experience. First, the use of pressure-type gas storage was a mistake, even though it was considerably cheaper than would have been the installation of a lift-type gas holder. The Butler gas holder is a cylindrical tank 10 ft. in diameter by 20 ft. long, which operates at a maximum pressure of 50 p.s.i. Its capacity is about 6,800 cu. ft. of gas measured at digester pressure; thus, its available storage capacity between 0 and 50 p.s.i. is approximately 21,000 cu. ft. of free gas. A compressor was provided to force surplus gas into the tank whenever the rate of gas production exceeded the rate of its consumption. Because the maximum digester pressure is only 8 to 10 in., it was necessary that the controls for starting and stopping the compressor be very delicately adjusted. If the compressor did not start soon enough, gas was wasted; if it ran too long, the pressure in the gas distribution system was unduly reduced and, possibly, a partial vacuum might be formed and a serious hazard be created.

Controls

The original controls were of the mercoid type and were not equipped with indicators for either the starting or stopping pressures. Maintenance and adjustment of these controls proved very troublesome, a difficulty that increased as time went on, until it became practically impossible to obtain ideal compressor operation. In 1947, the control was replaced by a low-pressure switch having three indicators, each of a different color. One measured the actual gas pressure in the distribution system ahead of the compressor over a scale of 0 to 10 in. of water; the other two were adjustable by means of knurled screws to any desired point on the scale. When the pressure indicating pointer contacted one of the others

* Presented at 21st Annual Conference, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; Aug. 24–26, 1949.

TABLE I.—Economics of Power Generation at Butler, Pa.

Period Covered	Jan.–Dec., 1941, incl.		July, 1946–June, 1947, incl.	
Engine operation time (hr.)	8,505		7,272	
Power generated (kw.-hr.)	236,520		228,940	
Power purchased (kw.-hr.)	6,620		68,360	
Power consumed (kw.-hr.)	243,140		297,300	
Estimated value of power [1]		$3,373.44		$3,915.00
Operating costs and fixed charges:				
Purchased electric power	$383.80		$1,573.72	
Purchased natural gas	312.80		0.00	
Oil and lubricants	177.20		135.50	
Ignition repairs	40.93		34.50[2]	
Tachometer repairs	25.00		0.00	
Annual general overhaul	200.00[2]		250.00[2]	
3% Interest on first cost [3]	360.00	$1,499.73	360.00	$2,353.72
Annual saving [4]		$1,873.71		$1,562.70

[1] Based on power company schedule and a maximum demand of 37.5 kw.

[2] Approximate.

[3] First cost estimated at $12,000, including engine, generator, gas holder, and applicable portions of building and electric panel. Due to P.W.A. grant the City bore only 55 per cent of this cost.

[4] Exclusive of operating attendance.

the compressor was started; when it contacted the second, the compressor was stopped. Thus, it was always possible to tell at a glance the setting of the start and stop points, the actual gas pressure, and whether or not the compressor should be running. However, even with this type of control, pressure storage is not considered as satisfactory as a lift-type gas holder.

The rate of gas production in the digester varies over wide limits, as discussed in detail later. Unless the compressor is made unduly large, there are times when some gas is wasted because the rate of gas production exceeds the capacity of the compressor plus the rate of gas consumption. If the compressor is made unduly large, it starts and stops so frequently that difficulty may be encountered in maintaining electrical contacts and, at best, a highly fluctuating gas pressure prevails in the distribution system. With a lift-type gas holder to which all digester gas is piped, and from which it is withdrawn as needed, no gas can be wasted unless the holder is full.

A study of gas wastage and purchases at Butler during the years 1940 to 1944, inclusive, shows that gas had to be purchased during 47 of the 60 months. However, for 30 of the same 47 months, the volume of gas wasted exceeded the volume of gas purchased.

When the private supply of natural gas failed in 1945, some consideration was given to the installation of a lift-type holder, and a connection to the local gas company system. However, it soon developed that even this company was having difficulty in supplying the winter gas requirements of the community and that one large industrial user was converting many of its gas-fired furnaces to oil combustion units. Therefore, this plan was given up and it was decided that any future additions or alterations to the gas utilization system at the Butler sewage treatment plant should be predicated on obtaining more efficient

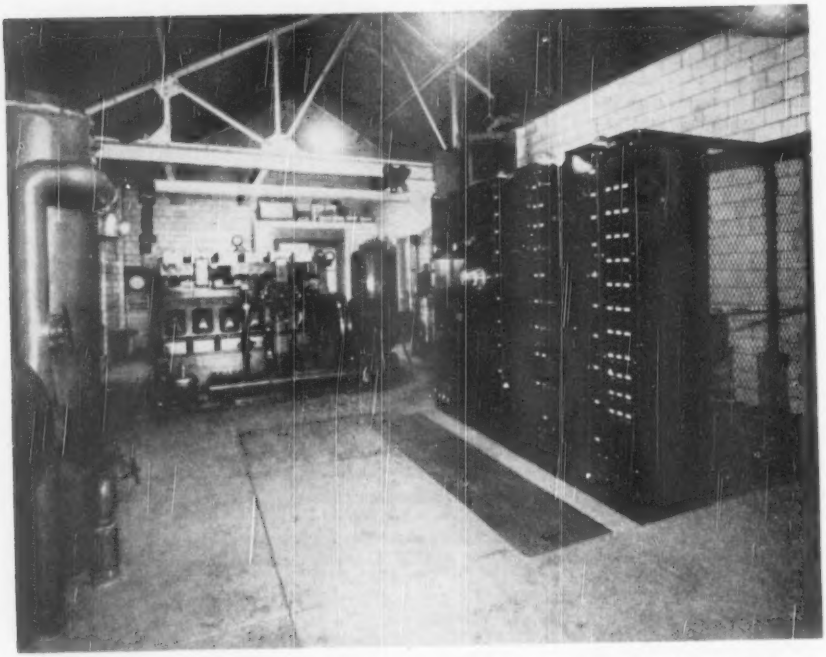


FIGURE 1.—Gas engine-generator unit at Butler, Pa., sewage treatment plant.

use of the supply of sludge digestion gas and not on the augmentation of that supply with an auxiliary source of gas.

Design Problems

Whenever a designer is faced with the problem of installing a gas engine to operate on digester gas, he must always choose between the installation of a gas engine-driven generator, the output of which can be utilized to drive any or all of the various motor-driven equipment in the plant, or the installation of one or more gas engines direct-connected to pumps, blowers, or similar pieces of equipment, that operate practically continuously and consume considerable amounts of power. If this latter course is followed, then motor-driven standby equipment must also be provided to take care of engine shut-down periods. The final decision must be based on local factors. However, there are certain mechanical relationships which are pertinent to the solution of all such problems.

Obviously, neither an electric generator nor an electric motor is 100 per cent efficient. Even assuming 90 per cent efficiency in each of these units, it is obvious that only 83 per cent as much usable power can be obtained from the gas engine-generator set-up as could be obtained from a direct-connected engine. However, there are still other mechanical relationships which further favor direct connection of engines to pumps or blowers.

Manufacturer's literature on gas engines generally shows the fuel consumption to vary with the horsepower output. For example, the manufacturer guaranteed the following fuel

consumption for the Butler engine (Figure 1):

Efficiency (%)	Output (b.hp.)	Fuel Consumption (B.t.u./b.hp.-hr.)
100	80	11,000
75	60	12,500
50	40	17,500
30	24	24,000

The horsepower output of any engine is a function of the product of its torque times its rotative speed, and actually the fuel consumption varies with the torque, not with the power output. That is, if the speed of the engine could be reduced to 300 r.p.m., it would operate practically as efficiently at a 40-hp. output as it now operates at 80-hp. output and 600 r.p.m.

When an engine is driving an a.c. generator, it must operate at constant speed. Otherwise, the number of cycles, and hence the speed and efficiency, of all motors operating on the generated power will vary. Thus, the manufacturer's tables on variation of fuel consumption with horsepower output are strictly applicable to generator service. However, if the engine is driving a blower or pump directly, it is not only permissible but even desirable to vary its speed in accordance with air or flow requirements. Although a constant torque cannot be maintained even in these cases, the ability to vary speed does materially reduce the variation in engine torque over what would have been necessary had the engine been driving a generator. Thus, considerable economy in fuel consumption is possible.

Furthermore, if it is desired to operate almost an entire sewage plant from a single generator, as was the case at Butler, then that generator must be at least large enough to supply the maximum starting current of the largest motor. Unless other operating motors are temporarily stopped or transferred to another source of power, the generator must be large enough to carry also their normal operating load without undue voltage drop. Although the Butler plant has these transfer switches, the 50-kw. generator is still none too large to permit starting the 30-hp. pump motor. However, during normal operation the actual load on the generator is only about 30 kw. This means that the engine output is only 45 to 50 b.hp. most of the time, and hence a fuel consumption of less than 15,000 B.t.u. per b.hp. cannot be expected. With a 580-B.t.u. net heating value of the gas (as determined by a few scattered analyses) this means that about 30,000 cu. ft. of gas per day are required to operate the engine. Actual operating records show that as long as the mixing valves are properly adjusted and the rotative speed does not vary, the gas consumption remains quite constant, regardless of the load on the engine, and usually ranges from 28,000 to 33,000 cu. ft. per 24 hr.

Gas Production

A study of gas production at Butler over a 357-day period in 1946 and 1947 showed that although the average daily gas production was about 28,000 cu. ft. per day, the variation ranged from about 10,000 to 42,000 cu. ft. Yields in excess of 29,000 cu. ft. per day were obtained on only 91 days. However, there was only one day when gas production was less than 13,500 cu. ft. and only 28 days when it was less than 19,000 cu. ft.

Minimum gas production usually occurs during the extreme wet weather of early spring, when heavy snows are melting and ground water infiltration is at a maximum. Under such conditions, sewage flows in excess of the capacity of some of the pump stations or of inverted syphons under the creek are encountered. Therefore, some raw sewage overflows to the creek and the solids contained therein never reach the plant. At the plant, settled sewage in excess of 3 m.g.d. is by-passed and so does not have an opportunity

to produce any secondary sludge. Furthermore, there is a tendency for the trickling filters to clog or pond at this time of the year, so that the amount of secondary sludge solids available for digestion is further reduced. At this time of year considerable heat is required, not only for the digester, but also to maintain workable conditions in the plant buildings. If the gas engine is not operating, no heat is available from its cooling water and gas must be burned in a hot-water boiler. The fuel requirements of this boiler (ranging from 8,000 and 18,000 cu. ft. per day, depending on heat requirements) reduce the amount of gas that can be stored for future use in engine operation.

Under such conditions it is obvious that the gas engine-generator cannot be operated continuously for more than 3 months out of the year, and that the maximum demand for outside power will exceed the 22½ kw. on which the minimum power bills are based. As a result of this condition, monthly power bills have run as high as $263, and for four consecutive months (January to April, inclusive, 1947) the power bills exceeded $200 at the sewage plant alone, exclusive of the power consumed at the various pump stations. Maximum demands as high as 46 kw. have been recorded by the power company; however, they are usually less than 40 kw.

Second Gas Engine

In an effort to avoid building up such excessive demands, as well as to utilize the available gas more efficiently, consideration was given to the possibility of substituting a small gas engine for the 30-hp. motor on the larger of the two settled sewage pumps. After contacting a number of engine manufacturers, a gas engine was found that could be admirably adopted to this use. This engine-pump combination, when operated at 700 r.p.m., would deliver 2.1 m.g.d. and would consume 8,300 cu. ft. of gas per day; when operated at 1,000 r.p.m., it would deliver 4.6 m.g.d. and would consume 19,000 cu. ft. of gas per day. In addition, it could be equipped with controls so that, as long as sufficient gas was available, the speed of the engine could be automatically varied in accordance with the liquor level in the wet well. However, if necessary, during periods of extremely low gas production, the engine could be slowed down to 700 to 800 r.p.m., and run constantly at this speed. Under such conditions gas consumption would not exceed 11,000 cu. ft. per day and sewage delivery to the trickling filters would be from 2 to 3 m.g.d., or about the same as is now pumped to them during the winter months.

Engine cooling water could be utilized to satisfy part of the heating requirements of the buildings and sludge digestion tanks. At the time of the installation of the original gas engine-generator unit, an economizer was installed to permit recovery of heat from the engine exhaust. Subsequent experience showed that this economizer was not needed and so it has been used very little. However, it is still available for use. By connecting the exhaust of the new engine to this economizer, it is believed that sufficient additional heat will be recovered to make it unnecessary to ever use the gas-fired boiler. Thus, during the winter months of low gas production, practically all of the gas may be utilized by the new engine, and as it is direct-connected to a pump and capable of speed variation, such utilization will be much more efficient than can be obtained in the existing engine and generator. If gas production exceeds the demands of the new engine, it will be stored in the existing pressure-type gas holder. Whenever the pressure in that holder approaches 50 p.s.i., the new engine may be shut down and the large generator started up; its operation can continue until such time

as gas pressure in the holder drops to a few pounds. As there should never be any occasion to use outside power for pumping sewage, so high maximum demands should not be encountered.

The new equipment is just being installed. By its installation, it is hoped to keep the maximum demand below 25 kw. and all power bills below $170 per month. Had this engine been in use from July 1946 to June 1947, inclusive, the annual savings in power costs would have been about $460. Although this saving is not large, it represents a good return on the additional investment. After the installation, it is believed that the Butler set-up will be considerably more flexible than it has been in the past with only a gas engine-generator set, or than it would have been with only duplicate engines direct-connected to pumps.

WHAT OPERATORS WANT IN SEWAGE PLANTS *

Chairman Leroy W. Van Kleeck, Principal Sanitary Engineer, State Department of Health, Hartford, Conn.: —In this discussion it is hoped to gain the ear of the consulting engineer. Unquestionably, a keen operator can contribute to better design and better treatment through his intimate knowledge of the operation of his plant and his observation of practical conditions and effects. What the operators have to say surely should be worthy of attention.

Uhl T. Mann, Superintendent, Sewage Treatment Plant, Syracuse, N. Y.: —Someone has said that the perfect sewage plant is yet to be built. I am sure most operators will agree. The answer to what operators want in sewage treatment plants can be easily stated in very few words—better treatment plants.

Probably, the most important factor affecting the success or failure of a sewage treatment plant is that of planning by those responsible for the project—planning in the broad sense. Such planning should include the correlating of all the various groups having an interest in each sewage treatment plant; namely, the public, government agencies, manufacturers, contractors, and the operator. In some instances there is overlapping of interests and in others there is a wide gulf. It is not proposed to say who should take the lead in correcting this fault, as that will vary with circumstances. Such a solution, however, will give sewage plant operators what they want most—better sewage plants.

The actual building of a plant can be done piecemeal, but the planning should be long-range and thorough. For example, the following might be credited to lack of planning, to poor planning, or even to no planning:

1. Poor sites.
2. Wrong types of plant.
3. Lack of capacity.
4. Poor design of units and layout.
5. Improper operation.

The last item may sound strange coming from an operator, but it is believed that the designing engineer should have an inherent responsibility to see that his creation is used as intended and to the best advantage.

Still another case, which it is agreed is rare, is the sewage treatment works designed and built for a community that later discovers it is financially unable to operate the plant in a manner

* From transcript, 1949 Operators' Forum, 22nd Annual Meeting, Federation of Sewage Works Assns.; Boston, Mass.: Oct. 17–20, 1949. [One of six subjects discussed; discussions of other subjects have been published in THIS JOURNAL, **22**, 2, 245 (Feb., 1950), and **22**, 3, 357 (Mar., 1950).]

in keeping with the plans of the designer. Any plant operated in an inefficient manner defeats in a large sense the purpose for which it was intended. This is a good example of lack of thorough planning by all the agencies involved.

These comments are very general, in order to speak for all operators. To speak for myself on what I want in a sewage treatment plant would take all morning. What operators want in sewage plants can best be summarized by a plea for greater mutual cooperation in the direction of planning and working together for the betterment of sewage treatment as a whole. The final result will be—better sewage plants.

J. K. Adams, Superintendent, Sewage Treatment Plant, Tenafly, N. J.: —Both operators and manufacturers would derive benefit from more frequent visits at treatment plants by technically trained representatives of equipment makers. The manufacturers would gain first-hand information on how their products are standing up under varying usages. Improvements in design or materials might be expected from such observations, and undoubtedly the operator could pick up useful suggestions from these contacts. The broader experience of the manufacturer should enable him to suggest changes in technique or maintenance that would be valuable to the operator.

As long as there are sewage plants, operators no doubt will be hoping for easier and better methods of dewatering sludge. Mechanical means are so far limited for all practical purposes to the vacuum filter and it is to be hoped that improvements in the design of these units will result in reduction in time out of service for repairs and such ordinary maintenance as changing covers and renewing the wire mesh supporting the cloth covers. Could not removable sections be designed that could be quickly set in place and held tightly by screws or clamps so that winding wire and cross wires could be dispensed with?

Operators would also be happy to see more resistant alloys used in vacuum and filtrate pumps from handling low pH filtrates. I would like to put in another plug here for Saran pipe, which we have used on our vacuum filters since 1944. Not a single leak has occurred in this pipe, although it is in continual contact with filtrate containing ferric chloride with a pH around 4.0 or 5.0.

My third suggestion has to do with design and is entirely impractical with regard to benefiting any existing plant. Perhaps, however, some operator in a plant yet to be built may be saved some headaches if the plant engineer will design so that, unlike our plant, the underdrains and the bottom 6 in. of sand in the sand filters will not be continuously immersed in water. This results in a dark layer of organic matter that aggravates the hydraulic deficiency and results in poor drainage. Another foot difference in evaluation would have improved tremendously the operation of these sand filters.

For the removal of screenings taken out by an automatically cleaned bar screen or for a hand cleaned screen, unless the quantity involved is exceptionally small, I would like to see the operator relieved of the disagreeable and primitive task of hauling these away in a wheelbarrow or a bucket. The ideal way to move such material is with an air ejector, a device of moderate first cost and low maintenance expense. Final destruction in an oil burning incinerator would be the perfect end to this unpleasant step in solids removal. This method of disposal would not apply, of course, to plants equipped with primary settling tanks, either with or without one of the several screenings grinders on the market. We have neither of these at Tenafly.

Where low-pressure air is available for aeration tanks or other stirring

operations the plant operator may find it advantageous to use a small amount of this air for lifting the return sludge or the excess sludge, before dewatering. The air lift is a very simple inexpensive device with no moving parts for raising liquids short distances against low heads. There is no piece of equipment in our plant which does its work 24 hr. a day with so little maintenance or attention by the operator.

We have made another very helpful use of air. A small hole was tapped back of the return sludge adjusting valve so that whenever a stoppage occurs in the return sludge line, which happens once or twice a year due to grit, we just hook a hose on to that nipple and turn on the air. It is only a matter of minutes before the whole line is cleared.

I read recently (THIS JOURNAL, Sept., 1949, p. 918) of the difficulties experienced at Buchanan, Mich., in emptying a digester because the drainage pipe was not at the bottom of the tank. We are free from digester troubles, not having these units; but complaints are loud and vigorous every time we empty an aeration tank. The tank bottoms are either flat or, in some instances, slope away from the drain. We have to use a gang of men in boots, with brooms, to push the last 6 in. of mixed liquor from one end of the tank to the other. Surely a tank could be designed so as to maintain a uniform static head on the diffuser plates and yet permit the tank to have an adequate pitch toward the drain. How about using a tapered plate holder box with its top side level and its base sloped to conform to the slope of the tank bottom? Another caution—where plate holder boxes are set on the tank floor at right angles to the direction of drainage flow, wide enough openings should be provided to allow the liquid to pass the boxes and not be trapped behind them.

Another point, which may be a luxury item, is an aerometric device for each aeration tank separately. We have wanted a number of times to compare the effect of different factors, such as solids, on detention period and load, and have found it impossible to measure the air that each tank was receiving. The final D.O. is measured and the flow through the tank is known, but we still don't know the whole picture. It would be very useful if a device could be produced to secure that information.

R. H. Ritter, Partner, Whitman, Requardt and Associates, Baltimore, Md.:—I have heard the complaint for 20 years that the engineer doesn't get down to the operator, and I have made it a personal point to do just that. However, I thoroughly agree with the operators that every arrangement should be made to satisfy them in small things that do not cost too much money in the aggregate. For instance, the design of an aeration tank as proposed might be expensive. Nevertheless, we have to give and take sometimes, and some of us younger engineers are listening to the operators.

F. W. Jones, Partner, Havens and Emerson, Cleveland, Ohio:—I'd just like to say, speaking for only one consulting engineering firm, but I am sure they will all agree with me, that we do want to give full consideration to the operator. On my very first job (and that was a long time ago), we had a vertical pump that got plugged up. I had to clean it, and I took all the skin off the back of my hand getting down under. Ever since, when I have had anything to do with a pump it has been placed where an operator can get at it. Although there are many things that occur in the design where we are always pleased to consult an operator, our experience often has been that the operator thinks of the things he'd like after the plant is built, not before. Then again, once in a while an operator will find that

some of the things he gripes about aren't as bad as he thought they were in the beginning.

V. P. Enloe, Superintendent, Clayton Sewage Treatment Plant, Atlanta, Ga.:—It would be nice if all plants had some place for the operators to eat their lunch. That is one item.

Also, I'd like to add to what has been said about drains. One of the best things about a plant are floors that will drain, not only in the bottom of aeration chambers or digesters, but also elsewhere. I wish I didn't have a floor in my own plant that was level, providing each one sloped toward a drain.

E. R. Howard, Assistant Design Engineer, Bureau of Public Works, The Metropolitan District, Hartford, Conn.:—I'd like to bring up one point in connection with digesters that also has appealed to me; that is, an access manhole at the bottom of the vertical wall, so that when the digester is emptied, it is possible to get in there and work with less difficulty than going clear to the top and climbing down inside.

J. O. Barrett, Superintendent, Westerly Sewage Treatment Plant, Cleveland, Ohio:—I know of one digester wherein very elaborate precautions were taken just to be able to do that, and to my knowledge those plates have never been off. We have a fine plate, and I like the design, but I would suggest that they be installed where some means is provided for carrying the grit away. Ours happens to open in the basement of a chamber where it is just as hard, if not harder, to get the grit out as through the roof of the digester itself. The manhole was put in at the suggestion of an operator, too. The suggestion was good, but the result was misplaced.

W. E. Merrill, Public Health Engineer, State Department of Health, Boston, Mass.:—A number of good plants have been built, with everything an operator desires. After the plants are built, however, it is almost impossible to get competent men to operate them at the salaries paid. I have in mind one treatment plant that cost $300,000 or $400,000 to build. After it was completed the operators hired were very low grade. The plant is only 7 years old, but requires an expenditure of $98,000 for repairs. Better men, paid adequate salaries, would have given better plant operation and been an economical investment all around.

THE DAILY LOG

Aurora, Illinois

By Walter A. Sperry, *Superintendent*

December 1—"Mayor has deplorable condition remedied in overflow sewer at the foot of Rathbone Ave. While this will help a great deal and is a big step in the right direction it is only a temporary measure. Experts say the only way to really solve this problem is to continue large sewer pipe into center of stream."

This caption appeared recently on a picture in a small weekly advertising newspaper carrying a few paragraphs of often heckling news. It presents an interesting public relations problem. The "experts'" names were not stated. Examination of the facts reveals that the apron of the sewer originally was cut off at the ends of the wing walls of the 8-ft. combined sewer, and the storm flows gradually washed a sizeable and deep pool at the end of the apron (Figure 1). Thus, the flow could not all drain down the 200-ft. channel to the river. During the sum-

mer this pool created small local odor nuisances due to the sanitary sewage carried; the paper protested. The remedy applied was to fill the pool area with gravel and rock, which was then surfaced with a slab of concrete, so that the channel could drain to the river. Evidently, this solution did not satisfy the editor.

December 16—The highway superintendent came rushing in at noon, during a heavy rainstorm, to say that a manhole cover was dancing some 8 in. above its ring on a head of water boiling up out of one end of the Montgomery Bridge river crossing siphon. Our men rushed down immediately and threw a temporary earth dam around it to divert the water to the river and off the highway.

FIGURE 1.—Pool scoured by storm flows at outlet of 8-ft. interceptor.

Later, a study of the whole system resulted in a very muddy pair of good trousers and the sure knowledge that the 16-in. pipe of the siphon system was plugged. A local plumbing firm was called to clear the stoppage with Rotorooter equipment. It is almost certain that some planks are lodged in the siphon and that it is well filled with clay and snail shells, possibly as the aftermath of a break in this system some years ago.

December 21—A regional park engineer called for our immediate presence to decide how and who was to repair a break in a 24-in. interceptor belonging to the District and running through a new park development. The sewer had but 1 ft. of cover and by good fortune the break was discovered by the bulldozer operator before he ran into it. It was uncovered and cleaned out. The bottom half was sound, so the break was covered with a piece of heavy galvanized sheet iron extending well onto the sound ends. Then some 2 cu. yd. of "redimix" concrete was dumped onto it, being careful to carry the concrete well down on the sides and to firm earth. Afterwards, some steel highway reinforcing mesh was well embedded in it and a cover of earth applied to prevent freezing.

January 5—Unusually heavy rains in December (6.3 in.) and an additional 2 in. so far this month caused the river to rise and completely flood out a siphon crossing. Dilution by both storm and ground water has lowered the B.O.D. of the raw sewage from 160 p.p.m. to 60 p.p.m., and the suspended solids from 200 p.p.m. to 115 p.p.m. and less. Gas volume has dropped from 45,000 cu. ft. per day (Dec. 1) to an all-time (20-yr.) low of 6,400 cu. ft. per day.

Because of insufficient gas, even the heating boiler was out of operation, and the screen house incinerator was shut down. Screenings were hauled out and dumped and the water pipes began to freeze. Office and workroom temperatures were 50° to 55° for days. In addition, the digester temperatures dropped gradually from 88° or 90° to about 65°, which also added to the loss of gas production. Additions of cold sludge during this period only aggravated the situation.

Meanwhile, the pump engines and filters were shut down and the generator engines were switched to gasoline fuel. However, a good half day was required to dismantle and clean the carburetors of the gas-gasoline fueled engine because the fine gasoline jets were fouled by the long period of operation on gas. The combining of two carburetors in a dual-fueled engine may not be the best design.

January 6—Of course, the gasoline fuel pump would pick now to act up.

A float-operated motor drives a rotary pump mounted in a 2-gal. tank to supply the engines from an outside storage tank (an insurance requirement). The outfit became temperamental, running a few hours and then stopping. A slight twirl of the shaft with the fingers would start it, but the cause could not be found. The motor had been rebrushed and was in excellent condition. Despite overhauling of the pump, and then replacement with a new pump assembly, the same temperamental operation persisted. Finally, in desperation and to protect the night man from engine stoppages, the supply pipes were broken and rubber tubing was placed to siphon gasoline directly from the tank to the engine. It was quite a trick to start the siphon, but it was accomplished by connecting a Gooch filter flask in the tubing to avoid a gasoline "cocktail" while sucking to exhaust the air. After a few hours, this too failed, due either to air bubbles or to the volatile nature of gasoline. Finally the pump was reassembled and the chief day operator found that by disconnecting the float and allowing the motor to run continuously, with the surplus gasoline draining back into the supply tank, the apparatus ran like a charm.

January 9—During this low gas period it has been questionable, when leaving the plant at night, whether or not the row of emergency kerosene lanterns will have to be used before morning. This morning, however, we arrived to find the plant in confusion and excitement. During the night two sharp explosions in the big muffler (an iron drum, about 15 ft. long and 2 ft. in diameter, mounted on brackets on the pumproom wall) almost scared the night operator out of a year's growth. No damage was done to the muffler, but the gasket was blown out of the long inspection plate and an oily soot filled the whole room. The night operator was as black as the ace of spades and it took 3 men all day to clean up the mess.

The monthly Board meeting had to be held downtown (in the District Attorney's office). It did not take much persuasion on the part of the District's superintendent to secure authorization to purchase an oil burner for one of the two gas-fired furnaces.

January 10—Among the lesser annoyances that plague us during this low gas period is the failure of the motor on the sump pump in the pump room. Twenty years of service, however, in the slight but constant presence of H_2S, well justified a new armature and rewinding. The failure necessitated rigging an ejector with piping and hose lines, but due to frequent engine off-periods we cannot prevent occasional floor flooding to add to our discomfiture.

With no gas available, it is necessary to protect the piping in the secondary tank pumphouse from freezing. An oil burning stove solves that problem, but it has to be refueled and attended to.

January 11—An oil burner for one of the gas-fired furnaces has been found and installed. Its purchase was well advised, as there are two or three periods of low gas production each year—none has ever been so severe as the present one, however. The first noticeable effect of the new burner was the comfortable temperature of the office, laboratory, and work room.

January 14—Gas formation has increased to 11,000 cu. ft. per day, a direct result of warmer water in the digesters. Undoubtedly, as the digester temperature comes back to its normal of 88° to 90° there will be a large surplus of gas. Sludge records show that, with a temperature of 90° and with 5,000 lb. of equivalent dry sludge per day available, a gas yield of 45,000 cu. ft. per day can be expected. During most of the low gas period just passed, there was nearly as much sludge available as usual, but

the digester temperatures were about 20° below their normal operating level. The next phase should be of interest, as we will probably have more gas than we can handle!

January 15—Glancing back over the entries of the last 6 weeks calls to mind that: "There was a man in the land of Uz whose name was Job and that man was perfect and upright and one that feared God and eschewed evil" (Job 1:1). We sewage plant operators, too, are faithful, alert, and loyal to our duties. Nonetheless, troubles descend upon us even as they did on Job. And like Job we usually are equal to the occasion, for Job 42: 16-17 tells us: "After this lived Job an hundred and forty years . . . (and) died being old and full of years" (and prosperous). Now that things have quieted down, the thought persists that these periods of trouble are good for us. They help to tie the men together as a team to lick a given situation.

EXPERIMENTS IN COMPOSTING DIGESTED SLUDGE AT AUSTIN, TEX.

By A. H. Ullrich and M. W. Smith

Supt., Water and Sewage Treatment, and Asst. Supt. and Chemist, Sewage Treatment, Austin, Tex.

Austin's present sewage treatment plant was placed in operation in May, 1937. It is a conventional activated sludge plant with primary settling and separate two-stage sludge digestion. The digested sludge, which contains an average of about 6 per cent solids, of which about 57 per cent is volatile, is pumped to conventional drying beds. When sufficiently dry the sludge is stripped from the beds and ground in a hammer mill, to be sold as fertilizer. To a few customers who can use unground fertilizer, the dried sludge is sold directly off the beds.

Although Austin has never advertised the sludge fertilizer through paid advertisements, a remarkable demand for it has developed. Golf clubs use it on both their greens and fairways. The University of Texas uses it on its athletic fields; a few farmers use it for starting plants, and many home owners use it for fertilizing their lawns and shrubs. It has found favor for these purposes not only because of its quick yet lasting fertilizer value, but also because it does not "burn" plants easily and because it is almost entirely free from weed and objectionable grass seeds. At the present time the City is unable to supply the demand.

Although the digested sludge, when dried and ground, makes an excellent fertilizer, it does have an objectionable odor when used as a "spread" fertilizer and then wetted. This objectionable odor may persist from one to several weeks, depending on weather conditions when the sludge fertilizer is spread. It was, therefore, decided to conduct a number of composting experiments in an effort to find an economical method for removing the objectionable odor and at the same time improve, if possible, the fertilizer value of the finished product.

Sawdust and Cotton Burrs

Because the wet sludge as pumped from the digesters will drain only partially on the drying beds before sealing itself and the beds (Figure 1), a large percentage of the moisture is removed only by evaporation. It was felt, therefore, that if a suitable composting material could be added to and mixed with the sludge as it was pumped

FIGURE 1.—Digested activated sludge without admixture after 30 days on drying bed, showing wet sludge between surface cracks.

to the beds, the admixture might keep the sludge in a porous condition, thereby shortening the drying period, as well as providing an ideal means for obtaining thorough mixing for later composting. Consequently, in the first test 3½ cu. yd. of hardwood sawdust was mixed with 10,000 gal. of digested sludge as it was being pumped to a small drying bed on October 14, 1948.

The mixture, although wet, had a good appearance on the bed from the start and no clear water separated to appear on the top, as is frequently the case when sludge without an admixture is pumped. The sludge-sawdust mixture was inspected from day to day, and on the fifteenth day it was found that it would strip easily from the filter bed media (Figures 2 and 3). Therefore, on the 16th day, the mixture (although still relatively moist) was stripped from the bed and made into a pyramidal compost pile approximately 6 ft. square at the bottom. At the end of 3 weeks the pile was completely turned and, although no temperatures were taken, it was apparent that relatively high temperatures had developed inside of the pile. The pile was turned once more at the end of 8 weeks, at which time it was noticed that the material had become fluffy and had a sweet earthy odor in contrast to the objectionable odor of moist digested sludge.

FIGURE 2.—Sludge with hardwood sawdust admixture, being stripped after 17 days on drying bed.

FIGURE 3.—Granular sludge with hardwood sawdust admixture is readily spadeable for removing and composting after 17 days on drying bed.

The same experiment was repeated with cotton burrs as a substitute for hardwood sawdust. Apparently, the cotton burrs required a longer period for decomposition, but the end results compared favorably with the hardwood sawdust admixture.

Planing Mill Waste

On the strength of the results obtained with hardwood sawdust and cotton burrs for admixtures, a series of tests were started using various percentages of planing mill waste. This waste, as received, included a relatively small percentage of sawdust and wood powder, a large percentage of shavings, and some wood chips. It was, of course, predominately pine waste. The amounts of this waste, which as before was mixed with the sludge as the latter was pumped to the beds, varied for

different tests from 1 cu. yd. to 12 cu. yd. per 10,000 gal. of digested sludge.

In all cases, the mixtures were stripped from the beds as soon as practicable and plant personnel was available, the stripped material being stockpiled in piles of 20 to 25 cu. yd. each. The admixture of approximately 3 cu. yd. of planing mill waste to 10,000 gal. of digested sludge seemed to give the best results. However, it was found that all of the stockpiled material could be successfully ground in the hammer mill after it had remained in the piles approximately 90 days. All except the larger slivers of wood and wood shavings had disintegrated and the ground material was light, fluffy, and had a pleasing odor. It should be noted, of course, that no grinding of this material was attempted immediately after appreciable rains.

Concurrently with the tests using planing mill wastes as an admixture to digested sludge, one test was made in which approximately 6 cu. yd. of planing mill waste were added to 10,000 gal. of digested sludge as the latter was pumped to a drying bed. Instead of stockpiling this material as described above, after suitable drying the mixture was stripped from the bed and made into a pile approximately 12 ft. by 12 ft. at the base and 5 ft. high. A few shovels of soil were added while the pile was being formed in order to seed the mixture with soil bacteria. Six tubular air vents, 3 in. in diameter and fashioned from ¼-in. mesh hardware cloth, were inserted in the pile at 3-ft. intervals. An 8-point recording pyrometer was set up for recording the temperatures at various points within the pile. Temperatures were recorded in the middle of the pile at ¼, ½, and ¾ pile depths; at a ¼ point, also at ¼, ½, and ¾ pile depths; and at the bottom of the pile. One point of the pyrometer was used to record atmospheric temperatures.

Temperatures within the pile were extremely slow to rise during the first 5 weeks, reaching a maximum of 112° F. at ¼ and ½ pile depths. Other temperatures recorded during this period ranged from 75° to 110° F. The slow initial temperature rise is thought to have been due to the high initial moisture content of the material, this being 76.4 per cent at the time of stripping from the bed and formation of the pile for composting. After the second turning of the pile (5 weeks after the pile was first formed), the moisture content had dropped to 30 to 40 per cent and the temperatures increased more rapidly, reaching a high of 148° F. in the center. The other temperatures recorded during this period ranged from 120° to 130° F. This high-temperature stage persisted for approximately 6 weeks, after which the temperatures decreased and the composting reaction was considered completed. The finished material had a good odor and had the appearance of very rich soil.

A final experiment consisted of adding 1 part of sawdust to 3 parts of dried digested sludge as the latter was stripped from the beds, grinding the two in the hammer mill to reduce the sludge and at the same time mix it with the sawdust, then stockpiling the mixture and watering it at intervals. After about 8 weeks the mixture had lost its offensive sludge odor. The sawdust had not disintegrated as in composting. Neither was there any noticeable temperature increase during stockpiling. However, when the mixture was used as a "spread" fertilizer and watered, there was no objectionable odor.

Summary

Mixing digested sludge with sawdust or similar materials for fertilizer use under certain conditions removes the offensive sludge odor. In the case of the Austin plant, mixing the sawdust directly on the drying beds permits the material to be stripped from 1 to 3 weeks sooner after sludge pump-

ing. When handled in this manner, the mixture may still have a high moisture content, but it can be stockpiled and ground at a later date. After proper ageing it will have the appearance of good compost.

To obtain rapid and true composting of digested sludge and pine sawdust, considerable care must be taken in making the compost piles and the material must be turned several times. This involves appreciable labor or equipment costs. In the Austin plant, where odor removal is now the chief objective, it may not prove feasible to resort to rapid and complete composting of this material.

Where sawdust or like materials are readily available, or where they cause a definite disposal problem, their use as an admixture to digested sludge fertilizer seems to offer advantages. Of the materials tried at the Austin plant, hardwood sawdust was the most desirable because it decomposed more readily than did pine sawdust or planing mill waste.

Acknowledgments

The authors wish to acknowledge with thanks the many helpful suggestions received from Brother Marcus, farm director of St. Edwards University, and the assistance of A. D. Potter, of the Texas State Health Department laboratory, and V. M. Ehlers and A. T. Thompson, of the Texas Sanitary Engineering Division, Texas State Health Department.

TIPS AND QUIPS

Preaeration Data Wanted

Operators of treatment plants incorporating preaeration units are urged to send operation reports, data, and comments to Frank C. Roe, The Carborundum Company, Refractories Division, Perth Amboy, N. J.

Mr. Roe is compiling a comprehensive paper on the subject for the 23rd Annual Meeting of the Federation to be held in Washington, D. C., in October, 1950, and is anxious to secure all the background information and operating data available. To facilitate cooperation in submitting the material, Mr. Roe will be glad to furnish on request a simple 1-page questionnaire he has prepared that outlines the type of information desired.

No Cause for Alarm

Just in case you've been wondering, it is extremely unlikely that radioactive wastes will upset the functioning of biological sewage treatment plants. This comforting thought was expressed in a paper presented at the 22nd Annual Meeting of the New York State Sewage Works Assn., held in New York City, January 20–21, 1950. The reason, according to J. A. Lieberman, assistant sanitary engineer, U. S. Atomic Energy Commission, is that the biological organisms have a tolerance of about 400,000 times that of humans, and can assimilate or concentrate radioactivity on the order of 100,000 times.

In general, only two sources of radioactive wastes exist, at least as far as normal treatment plants are concerned. The first consists of radioisotope users, such as hospitals, industry, and research institutions; the second, of accidental spills in AEC plants or during transit. Trouble from either source is cut to an absolute minimum by rigid control on radioactive wastes through assured competence and dependability of isotope users, notification of State health authorities, and widespread dissemination of recommendation for disposal (see THIS JOURNAL, 22, 2, 195; Feb., 1950.) In any

event, the half-lives of the usual clinical isotopes are short (less than 14 days) and concentrations are comparatively low.

Measurement of the "hotness" of the wastes is, of course, a matter for trained personnel. Some idea of the small values involved are contained in the standards set for maximum permissible limits in drinking water of some of the commoner radiosotopes, such as P^{32} (4.87×10^{-9} p.p.m.) and I^{131} (1.2×10^{-10} p.p.m.).

Anybody want to split an atom?

Sludge Pumping

The Guildford Rural District (England), serving several villages that are comparatively isolated as far as sewage treatment is concerned, has worked out a method of sludge pumping and servicing that may well be adopted in other locations facing the same problems of dispersion, small labor force, and lack of funds. In addition to the three main plants, there are five smaller ones, each equipped with sedimentation tank, trickling filter, and final settling tank; primary sludge is either dried on beds or pumped to agricultural areas for disposal by the trenching method. Final tank sludge is usually pumped to mix with the raw sewage, except during the spring unloading period of the filters, when it is preferable to use sludge beds or land disposal.

No pumps are provided at the smaller plants; sewage flow is by gravity and sludge pumping is accomplished by a trailer-mounted pump serviced by a "flying" squad of four men. This crew, with the three men stationed permanently at the largest works, constitutes the entire personnel complement of the system.

The mobile squad visits each treatment plant where pumps are involved and each pumping station daily. Each gravity plant is visited three times weekly for tank cleaning and attention to filter distributors, etc.

Credit Line

Through an oversight, authorship credit was omitted for "The Sewage Plant Operator Has a Headache," published in last month's Corner (March, p. 375). The bard was Frank Woodbury Jones, consulting engineer of Cleveland, Ohio; the verse, the prologue to his paper on "Aspirin for Operators' Headaches," presented at the 21st Annual Conference, Pennsylvania Sewage and Industrial Wastes Assn., State College, Pa., Aug. 24–26, 1949.

Natural Sludge Concentration

It is apparent that the higher the solids content of both fresh sludge and digested sludge, the better the conservation of tank capacity, and the less the strain on dewatering facilities. In this connection, Frank Woodbury Jones, consulting engineer of Cleveland, Ohio, in a paper presented at the 1949 Annual Conference of the Pennsylvania Sewage and Industrial Wastes Association, called attention to the possibility that digested sludge will have a greater concentration of solids if drawn when the barometer is high than it will if drawn when the pressure is low.

All of which can be summed up in one of those jingles of the type so popular with amateur weather "experts":

Barometer high—draw sludge to dry;
Barometer down—leave sludge, or drown.

The Modern Way

Development of a rat trap that electrocutes the rat and sprays the carcass with a material that kills fleas and ticks puts man one up in his battle against the rodents. Masking the odor of the insecticide with the synthetic scent of some flower is obviously the next step. One thing that they can't find a substitute for, however, is the personal satisfaction derived from destroying another rat.

It's in the Bucket

City officials do not always appreciate the interest of their constituency in local problems. Certainly, however, the mayor of Sheridan, Ore., can hardly pass off with a shrug of the shoulders the following "Letter to the Editor" in the Sheridan *Sun:*

Polk County
Oct. 9, 1949

Dear Dean:

I seen in the nosepaper where Hizzoner the Mayor of Sheridan is a takin' off his coat an spittin' on his hands an snapping his galluses gettin ready ter tackel that there 200 thousin dollar sewer exposal bizzness. You all is sure lucky ter hev a "work shirt" mayor stid of a "stuffed shirt" one like sum towns. Now, Hizzoner, (I'll call you Hizzy cause it is more friendly.) Well Hizzy, . . . I haint no sewer expert but Ben Franklin wasn't no expert when he invented e'extricity, so here is my 2 bits worth. The cave men away back in histry never had no sewer problem. It warent till peepel got good an civilized that they started dumpin sewage in the rivers an lakes an then goin' swimmin in em. Than a couple of jillion years later one of them State unsanitary fellers comes a ridin thru Egypt in his chariot an sez "You is a pessel of stinkers, do sumpin about it." Then the Egyptians built the pyramids so they could dump their sewage inter them. Every day the citizens hed to build the pyramids higher so as to have more room fer sewage whicht they carried up in buckets. Perty soon the pyramids got so high the peepel went on a strike an said they would rather die than climb that cussed thing every day with a bucket of sewage. So they died an thet settled their sewage problem. Now, about Sheridan; iffen the tax payers wont vote no money ter build sewers an hev to carry it away in buckets like that unsanitary feller said, that is gona take sum plannin.

Might be you could build a long shelf down town fer to put buckets on. Each feller could hev his name on his'n like they usta do with shavin mugs in the barber shop. What a feller does with a bucket of sewage tho I dont know. Iffen you put it in the ground it contaminates the ground, iffen you put it in the river it poisons all the fish. You might send over acrost the ocean to India an get one of them fellers whicht does the rope trick. You know, where they throw one end of a rope up in the air an it stays there, then they climb that rope an disappear. You could hand him a bucket of sewage every time he started up. They aint no use a beatin' around the bush, Hizzy, you is gona hev to tell the Sheridan peepel sumpin like this. "The law sez we gotta hev a 200 thousin dollar City Outhouse. Whether the law is good or aint good don't make no difference, as your Mayor I got to abide by it. And the onliest place thet money is a comin' from is the tax payers. As your Mayor, when I think of all the scrimpin an savin an scratchin an scrabbelin it is gona take to raise that money I feel awful. In fakt I feel awful awful. As your Mayor, in fakt I feel like bustin out cryin'; cause one of them tax payers IS ME."

Yourn,
His iggnerent X

(EDITOR'S NOTE: In commenting on the buckets His Iggnerent X is referring to the statement made here at the Chamber of Commerce meeting a few weeks ago when a representative of the State Sanitary Authority said that Sheridan could build a sewer system or haul it away in buckets. . . .)

Tight Squeeze

Rather than tear up 2,210 ft. of concrete slab to install an important telephone cable under a North Dakota air base runway, engineers recently resorted to the "mind-over-matter" method of solving the problem. Key spot in the undertaking was occupied by an 18-oz. pet ferret, fitted with a harness, to which was attached a light string. It took the ferret only 20 minutes to traverse the length of the small-diameter conduit, dragging the string, which was used to pull through heavier cords, then steel cable, and finally the heavy telephone cable.

We've heard of ridge runners, rum runners, and joint runners, but "cable runner" is a new one. Wonder what the ferret would have done if he had met an obstruction in the tube?

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Arkansas Water and Sewage Conference	Robinson Memorial Auditorium, Little Rock, Ark.	Apr. 17–19, 1950
Kansas Sewage Works Association	Lamar Hotel, Salina, Kans.	Apr. 20–21, 1950
Montana Sewage Works Association	Florence Hotel, Missoula, Mont.	Apr. 20, 1950
Maryland-Delaware Water and Sewerage Association	Fort Cumberland Hotel, Cumberland, Md.	Apr. 27–28, 1950
California Sewage Works Association	Lafayette Hotel, Long Beach, Calif.	May 3–6, 1950
Pacific Northwest Sewage Works Association	Winthrop Hotel, Tacoma, Wash.	May 10, 1950
Michigan Sewage Works Association	Park Place Hotel, Traverse City, Mich.	May 22–24, 1950
New England Sewage Works Association	Hotel Sheraton, Worcester, Mass.	June 1, 1950
Alabama Water and Sewage Association	Alabama Polytechnic Institute, Auburn, Ala.	June 7–9, 1950
Central States Sewage Works Association	Indianapolis, Ind.	June 9–10, 1950
New York Sewage and Industrial Wastes Association (Spring Meeting)	Hotel Jamestown, Jamestown, N. Y.	June 12–13, 1950
Institute of Sewage Purification	Bournemouth, England	June 19–23, 1950
Ohio Sewage and Industrial Wastes Treatment Conference	Gibson Hotel, Cincinnati, Ohio	June 28–30, 1950
Pennsylvania Sewage and Industrial Wastes Association	Pennsylvania State College State College, Pa.	Aug. 23–25, 1950
West Virginia Sewage and Industrial Wastes Association	Hotel Pritchard, Huntington, W. Va.	Sept. 14–15, 1950
Iowa Sewage Works Association	Hotel Blackhawk, Davenport, Ia.	Sept. 19–21, 1950
Georgia Water and Sewage Association	Georgia Institute of Technology, Atlanta, Ga.	Sept. 20–22, 1950
Rocky Mountain Sewage Works Association	La Fonda Hotel, Santa Fe, N. Mex.	Sept. 27–29, 1950
Missouri Water and Sewerage Conference	Sheraton Hotel, St. Louis, Mo.	Oct. 1–3, 1950
Federation of Sewage Works Associations	**Hotel Statler, Washington, D. C.**	**Oct. 9–12, 1950**
North Carolina Sewage Works Association	Washington-Duke Hotel, Durham, N. C.	Nov. 13–15, 1950

Reviews and Abstracts*

Interim Recommendations on the Disposal of Radioactive Waste by Non-A.E.C. Users. Circular B-6, Isotopes Division, Atomic Energy Commission, Oak Ridge, Tenn.; or *Nucleonics*, **5**, 2, 22 (1949).

The National Committee on Radiation Protection has appointed a Radioactive Waste Disposal sub-committee to study the broad problem of radioactive waste and formulate recommendations for authoritative use. It is expected that this committee will require several years to present their recommendations. In the meantime a group of 24 radiological scientists representing industry, medical science, university research, and the Atomic Energy Commission met in Washington to consider interim recommendations for the disposal of radioactive wastes by off-commission users. Detailed recommendations were adopted for the disposal of radioiodine, radiophosphorous and radiocarbon by one or more of the following methods: dilution with water, air, or other media; dilution of the radioisotope with a stable isotope before final disposal; dilution with media such as concrete and burial; and confinement after reducing the bulk liquid waste by evaporation, precipitation, ion-exchange, or incineration. The concentrated radioactive materials of long life would be confined more or less indefinitely and materials of short half-life would be stored until the activity decays to a value which would allow disposal by dilution and dispersion.

L. R. SETTER

Psychological Factors in Atomic Warfare. By J. P. COONEY. *Am. Jour. Public Health*, **39**, 969 (1949).

Radiation hazards are additional hazards, which only add to the complexity and perhaps the severity of the other hazards of total warfare. Therefore, we must not and cannot concentrate on this phase of atomic warfare to the detriment of other defensive preparations in the "realistic" opinion of the author. It must be recognized that the casualties caused by the blast and burns of this weapon (the atom bomb) will be many times greater than the deaths caused by radiation. The erroneous idea must also be dispelled that the rescue work of the injured will be impossible due to residual radiation. The Hiroshima and Nagasaki experiences show that only 5 to 15 per cent of the deaths were due to radiation. Strategically the bomb was developed as a blast weapon.

The permissible radiation dose of 0.2 or 0.1 roentgen per day, or 0.3 roentgen per week, depending on the authority, is a desirable maximum exposure for day by day contact with radiation or radioactive materials to avoid late complications.

A distinction is made between the day by day "tolerance limit" and an acute exposure to radiation which might be tolerated in emergencies. Variable therapeutic experiences indicate that the median lethal dose is about 450 roentgens. Consideration is given to a limit of 200 roentgens as the acute total body radiation dose which may cause radiation sickness to 50 per cent of human subjects when delivered. The acute dose is compared to the not unusual multiple X-ray filming of a patient in a short period of time, which may well approach 25 roentgens, and full body radiation in doses of the order of 25 to 100 roentgens given to patients for treatment of various conditions.

The radiation hazard is further compared with other "acceptable hazards" from the standpoint of military necessity.

L. R. SETTER

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in THIS JOURNAL. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

Waste Disposal Symposium (A Review). *Nucleonics*, **4**, 3, 9 (1949).

Representatives of the U. S. Atomic Energy Commission and other government departments met with representatives of the sanitary and waterworks engineering associations for a two-day seminar on general problems of the disposal of atomic wastes. Some of the pertinent facts disclosed at the seminar include:

1. Persons living at near sea elevations receive, during a normal life span, about 2 roentgens of cosmic radiation as compared to 20 roentgens received by those living in the mountainous regions of the West. Many people are exposed at one time or another to the effects of X-rays or radium. One diagnostic chest X-ray is equivalent to about 10 r.

2. Experience with X-rays and radium has shown that if a group of people were given a single dose of 450 roentgens of gamma radiation about half of the group would die. However, most individuals could take 450 r. if it were given not in a single dose but in a series of small doses over a period of several months. Most individuals can withstand a daily dose of 1 r. indefinitely without apparent injury, although recent animal experiments have shown that 1 r. and even 0.5 r. per day produce detectable effects during the life span.

3. A factor of safety of about 10 was used in setting the permissible exposure limit of 0.1 r. per day primarily applied to persons working in A.E.C. installations and physicians and nurses working with X-rays. (Consideration is being given to revising this tolerance limit to 300 mr. per week or, presumably, 50 to 60 mr. per day.)

4. There is a tremendous difference between the amount of radiation a person can take in the body as a whole and what he can take in a small part of his body. On a field ½ in. square, a dose of 5,000 r. is not infrequently used to cure a small skin cancer. A scar will persist, but no harm is done. A tenth of this amount to the whole body would be enough to kill.

5. Bacterial cultures have been found resistant to as much as 200,000 r.; viruses have resisted hundreds of thousands of roentgens without effect; the lethal dose to 50 per cent (L.D. 50) for paramecium has been reported as 300,000 r. The L.D. 50 for the pupal stage of some insects is 150,000 r., 825 to 900 r. for the rat, and 250 r. for the guinea pig. Plants, in general, are more resistant than animals.

6. Exposure to internal radiation presents a more tantalizing problem, as specific fission product wastes or isotopes, when taken internally, may localize in harmful concentrations in certain parts of the body.

7. There are many millions more of radioisotopes produced or needed to be disposed of within A.E.C. than are distributed to off-area users. Most of the distributed radioisotopes (radioactive phosphorous and iodine) have fairly short half-lives, or are elements which are not specifically concentrated in a human body at the dilutions encountered after the experiment. There are as yet no large-scale users of radioisotopes in commercial processes.

8. When a thing is made radioactive there is no way to cancel the activity other than natural decay.

9. Induced activity in the air and dust of an air-cooled reactor pile and radioactive argon are the principal air contaminants at Oak Ridge National Laboratory. The dust is removed by filters and the remainder diluted and discharged from high stacks. Various air sampling and electronic instruments are used to monitor the air. The probable maximum concentrations of general radioactive contaminants in air beyond the A.E.C. area of control are 10^{-6} microcurie per liter for beta and gamma emitters, and 5×10^{-9} microcurie per liter for alpha emitters.

10. Most of the fission product liquid waste has no present use and is stored in underground tanks and allowed to decay. At Oak Ridge, some liquid wastes containing less than 5 curies per day enter the White Oak Creek, and after detention for decay and precipitation in White Oak Lake enter the Clinch River at a level of less than 5×10^{-4} microcurie per liter. The total radiation level in the water of the lake must not exceed 100 millireps per day. A dilution factor of 20 to 1,000 when the White Oak Lake discharge mixes with the Clinch River brings the contamination level many times below the safe concentration, currently placed at 10^{-4} microcurie per liter for beta and gamma emitters and 10^{-7} microcurie per liter for alpha emitters. Safety factors of

10 to 100 have been added to offset nonuniform mixing and biological, physical, and chemical factors of concentration. Routine monitoring of the water, mud, algae, and plant life permits a permanent record of radioactivity, both on and off the area.

11. Special containers are used to collect and store all but a few millicuries of radioactivity per month from laboratories at Argonne.

12. The plutonium production plant at Hanford produces the largest volume of waste and the greatest quantity of radioactivity found at any site. The waste disposal system resembles the one at Oak Ridge.

13. Radioactivity complicates the disposal of solid wastes in the atomic industry. Useful material and equipment are decontaminated and reclaimed for on-area purposes where possible; otherwise they are buried at a depth exceeding 10 to 12 ft. of earth cover in carefully selected burial grounds. The grounds are fenced, restricted, monitored, and permanent records are kept. Some waste materials are encased in steel drums, which are dumped in the Pacific Ocean many miles off shore.

14. Experiments are in progress for the removal of long half-life alpha emitters from liquid wastes by means of the activated sludge process. The radioactivity is transferred from the liquid to the sludge as the first step of a concentration and storage process.

L. R. SETTER

The Work of the Sanitary Engineer. By L. B. ESCRITT AND S. F. RICH. Macdonald & Evans, London, England. 689 pp. (1949).

This book, styled "a textbook on water supply, sewerage, and the sanitation of buildings," is based on a textbook by the late A. J. Martin, covering chiefly British practice and British law. As such, it presents an elementary textbook, which is of interest to those in the United States desiring a very general view of British sanitary engineering.

The book is divided into 59 chapters, of which two are introductory (23 pp.); four on law and administration (63 pp.); ten on water supply (127 pp.); eight on sanitation of buildings (77 pp.); nineteen on sewerage and land drainage (159 pp.); fourteen on sewage treatment (189 pp.); two on public cleansing (21 pp.); and appendices, bibliography, and index (35 pp.).

The chapters on sewage treatment are largely compiled, in general being quite out of date and at times misleading.

LANGDON PEARSE

Annual Report of Commissioner of Public Works, Fitchburg, Mass., for 1948. By J. M. PIERCE. 68 pp. (1948).

Included is the annual report (20 pp.) on the operation and maintenance of the sewage disposal plant, by W. Lamothe. During the year, the Imhoff tank and trickling filter treated an average of 3.95 m.g.d., or 90 g.c.d., from 44,000 population. The average monthly flow varied from 3.14 to 5.10 m.g.d. The removal of screenings averaged 2.9 cu. ft. per day. The operating data are:

	Design Basis	Average (1948)
Population	55,000	44,000
Per capita flow (g.p.d.)	125	90
Detention period, Imhoff tanks (hr.)	3	5.8
Area of trickling filters (acres)	2.12	1.86*
Load on filter (m.g./acre/day)	2.00	2.12

* In use.

The flow in the Imhoff tanks was reversed monthly, the skimmings averaging 2.9 cu. ft. per day. Of the 850,000 gal. of sludge pumped during the year, 100,000 gal. were lagooned, and 750,000 gal. went to the drying beds, which were cleaned twice during 1948.

The total cost of operation was $18,977.27. No analytical data are given.

LANGDON PEARSE

Report upon the Reclamation of Water from Sewage and Industrial Wastes in Los Angeles County, California. By C. E. ARNOLD, H. E. HEDGER, AND A. M. RAWN. Planograph, 159 pp., 9 plates (April, 1949).

The report outlines an extended project for reclamation of waste waters in an area with less than 20 in. mean annual precipitation and facing serious water short-

age if future growth expectations are realized.

The Engineering Board finds:

1. The critical shortage of water in sections of Los Angeles County can in some measure be alleviated by reclaiming spent or waste waters.

2. The system of trunk sewers constructed and operated by the County Sanitation Districts of Los Angeles County is so arranged as to permit the segregation of wastes which might otherwise so contaminate the spent waters desired to be reclaimed as to render them noxious and unfit for reclamation.

3. The existence of a complete and adequate sewerage system for use by the Sanitation Districts greatly minimizes the difficulties and costs of building and operating water reclamation plants.

4. The water which may be produced at spent water reclamation plants is of good quality, entirely acceptable, and better than some supplies obtained from underground storage or imported into the area.

5. The reclamation of a satisfactory limited supply of water from the spent and waste waters of the area may be accomplished safely and economically.

6. Amendments to the Los Angeles County Flood Control Act and to the County Sanitary District Act would permit these two agencies to finance, plan, build, and operate the necessary rectification and distribution works.

The report presents a statement of facts and findings. At present 95 per cent of the sewage and industrial wastes from the County is discharged at sea (over 100 m.g.d.). Spreading areas would be operated as slow sand filters. Reclaimed water could be used for agriculture, industry, and recreation, and for domestic purposes after blending with other underground supplies.

The estimated cost of reclaimed water per acre foot varies from $9.30 to $19.05, according to location, as compared with $15.00 per acre foot for surplus unsoftened Colorado River water, or $20.00 per acre foot for surplus softened water. The effluent of various small sewage works could be reclaimed at a cost ranging from $26.00 to $90.00 per million gallons.

The water reclamation process is discussed under local conditions and the need for new standards relating to use of sewage effluents. The quality of the water reclaimed depends greatly on the amounts of dissolved minerals present. Segregation of certain wastes, such as brine from oil fields, will be required.

The Public Health laws in California are cited. The use of reclaimed water in agriculture is limited by its constituents, particularly sodium, boron, chlorides, and sulfates. Industrial uses would be chiefly for cooling, fire protection, air conditioning, clean-up, and gardening. Tests are cited at Rio Hondo on augmenting underground supplies and at Whittier on spreading effluent. At present the Flood Control District is operating nine spreading grounds (962 acres) with a flood water capacity of 1,090 c.f.s.

Estimates are given on construction and operation cost of typical works at various localities. The use of existing sewage treatment plants as water reclamation plants is described, including Tri-Cities (activated sludge); Whittier, El Monte, Covina, and Azusa (primary settling plus trickling filter).

LANGDON PEARSE

Pre-Design Report on the Proposed Sewage Treatment Plant for the City of Tacoma, Wash. BY C. S. SEABROOK AND R. G. TYLER. 31 pp. (1949).

The sewage originating in the northerly portion of Tacoma and presently discharging along the southwesterly shore line of Commencement Bay will require no treatment. Due to adequate currents in this vicinity, the extension of existing outfalls to about 40 ft. below mean low water will insure satisfactory dilution and eliminate the deposits of solids along the shore.

The sewage originating in the southerly portion of the city and currently discharging into the City Waterway and the Puyallup River must receive primary treatment.

Because of the unusual water movements in, and the great depth of Commencement Bay, conventional primary treatment can be modified so as to consist of (a) primary sedimentation with flocculation; (b) the removal and destruction of all grease and floating material; (c) the chlorination of both sludge and effluent; and (d) the pumping of the raw sludge to a point of discharge in the Bay about 2,500 ft. from shore at a depth of about 200 ft.

The City Waterway is a long narrow arm of the Bay, subject only to tidal movements. The Puyallup River is a different problem. It will carry whatever is mixed with it quickly into the center of the bay. At the mouth of the river are fishing grounds, where grease or other floating material of sewage origin would be objectionable. Consequently, some treatment is required for the sewage from six sewers, with a present population between 60,000 and 70,000, and a flow of 100 g.c.d. A plant for 100,000 population is being planned, with an ultimate population around 200,000. The sewage contains around 71.2 p.p.m. B.O.D. and 62 p.p.m. suspended solids. Considerable infiltration occurs. The initial construction proposed will handle 10 m.g.d.

The report states that an effluent containing 60 per cent of the B.O.D. of the sewage would do no harm in the critical area. In a normal plant with sludge digestion, no sludge would go to the Waterway. The authors propose to eliminate sludge digestion and use part of the savings to make an effluent containing 40 per cent of the sewage B.O.D.

Commencement Bay is an arm of Puget Sound, approximately 5,000 acres in area, into which the Puyallup River discharges (28-year average, 3,300 c.f.s.; minimum, 350 c.f.s.; average minimum, 700 c.f.s.). The tidal range is 13 ft. From 500 to 1,000 ft. off shore, 100 ft. of depth is found, increasing to 500 ft. in the center of the bay.

The Pollution Control Commission requires at least 5 p.p.m. of dissolved oxygen. In August, 1944, the content varied from 4.2 in the City Waterway to 7 at the mouth of the River, and 8 at the center of the Bay. The City Waterway is the critical point.

Rates of reaeration are discussed, as well as the D.O. content of salt and fresh water. Tidal movements are expected to aid in dispersion and mixing.

The B.O.D. entering the bay is estimated at 57,000 lb. per day, including Puyallup (14,300 lb.), Carstens (6,400 lb.), and St. Regis (12,500 lb.). Assuming reaeration at the rate of 0.00022 lb. per sq. ft. per day, 5,000 acres will provide 48,000 lb. per day.

A survey in April, 1949, indicated, on the falling tide, *B. coli* per 100 ml. (M.P.N.) in the Waterway to be 12,000, in the Puyallup River 15,000, off the mouth of each 510, and in the bay from 260 to 390.

LANGDON PEARSE

Disadvantages and Advantages of Sewage Disposal in Connection with Agricultural Utilization. By JAN WIERZBICKI. *Gaz. Woda i Technika Sanitarna* (Polish), **23**, 198 (June, 1949).

The first instance of the use of sewage for agricultural purposes in Europe is reported to have been at Boleslawiec, Lower Silesia, in 1559. The sewage was used for irrigating 37 acres of forest land. In the latter half of the 19th century there was a marked increase in the number of sewage treatment facilities which were combined with the disposal of waste on land (irrigation fields). The rapid growth of the cities and the difficulties of increasing the area of irrigation fields (high cost and lack of adequate terrain) led to field overloading. In 1906 the agricultural groups of Germany stated that they were against the use of sewage for agriculture because of the difficulties of transportation and the high costs in comparison with artificial fertilizers. Where the fields were of adequate size (as at Leignitz and Breslau) the results were very satisfactory. Irrigation fields were considered an old fashioned method of treatment when compared with the biological methods in use. Few new irrigation fields were placed in use between 1905 and 1930. During the 10-year period prior to World War II a return to the use of irrigation fields occurred in some countries.

The disadvantages of this method include the large land area needed (12 to 24 persons per acre for plowed fields), the need for soil of suitable porosity, and the distance from town (because of odors and fly nuisance). In addition, if the water supply is taken from ground sources, the irrigation fields must be located downstream from the source of water supply. Distance is important because pumping costs are related to it. The maximum is considered to be somewhat less than 20 mi. Berlin now pumps some of its sewage a distance of 18.6 mi. to irrigation fields.

Many forms of plant life do not fare well when cultivated on irrigation fields. An exception to this are grasses, which flourish. The presence of many weed seeds also causes complications. A larger

labor force is required for the maintenance of irrigation fields than is required for biological treatment plants.

The operation of irrigation fields is associated with additional difficulties. Wastes must be taken over the entire year, a practice not feasible from the agricultural standpoint.

The irrigation of large areas has advantages in that it benefits the social economy. Several hundred thousand acres of arid ground could be irrigated with sewage, and the sewage has valuable fertilizer constituents (nitrogen, potash, and phosphates). Sewage also helps to increase the humus content of the soil. Irrigation fields could also be used with less pervious soils provided the dosage is regulated in keeping with the requirements of the plant life growing there. Only those cities located in lowlands would have difficulty in disposing of the sewage. In many places the sewage could flow to the fields by gravity.

In Wroclaw (Breslau) only 65 per cent of the land is allocated to grass at present. In the new fields that are planned 90 to 95 per cent of the area will be devoted to pasture.

CONRAD P. STRAUB

Economy of Sewage Sludge Gas Collection. By W. BUCKNER. *Gesundheits Ing.*, **70,** 15/16, 252–9 (1949).

The economy of heated and unheated sludge digestion tanks is compared. In addition to sewage sludge digestion, gas production from mixtures of sludge and garbage is used as a basis for calculations. From a heating standpoint: steel tanks for digestion are better than concrete; an organic insulation layer 6 to 8 cm. thick is best; heat loss of a 1,000-cu. m. tank at 30° C. is 6,500 cal. per hr. per cu. m.; surrounding the tank with a glass wall is economical because the heat absorption from the sun is equivalent to the heat losses; intermittent heat from the sun is equalized by the storage capacity of the digester; a heated steel tank built above ground is most economical; utilization of the heat present in supernatant liquor covers 60 to 80 per cent of heat losses, savings being as high as the remainder of the heat costs; hot water coil heating is economically the equal of steam heating, the former having economical advantages and the latter operation advantages; the small annual variations in heat requirements and the large storage capacity of well insulated tanks reduce the cost of construction of heating devices and equipment; and the water content of the sludge affects heat requirements greatly, hence sludge should be concentrated.

W. RUDOLFS

Experiments on Precipitation of a Trade Waste Sewage (Part II). By C. LUMB, J. P. BARNES, AND J. BLACKBURN. *Jour. and Proc.*, The Institute of Sewage Purification (England), Part 1, p. 96 (1947).

Halifax sewage contains a large proportion of industrial effluents, principally greasy wastes from textile industries. Some form of initial settling aided by chemicals has been necessary before final treatment by trickling filters or the activated sludge process. For years, sulfuric acid has been used at Halifax.

The problem of precipitation has been reviewed from time to time and laboratory studies were recently undertaken in order to study the various ferric salts. Tests were made on chlorinated copperas, ferric sulfate, ferric chloride, chlorinated copperas with sulfuric acid, and chlorinated copperas and lime.

Chlorinated copperas was found to be more effective than sulfuric acid, but was much more costly. Results obtained with chlorinated copperas were only slightly different from those obtained with ferric chloride and with ferric sulfate. Small amounts of chlorinated copperas used in conjunction with pH adjustment by sulfuric acid provided good clarification. This combination would be more economical than the use of chlorinated copperas alone.

Excessive amounts of lime were found necessary to achieve a reduction in the amount of chlorinated copperas required. It appears that chlorinated copperas removed some impurities from true solution.

T. L. HERRICK

Mechanical Filtration of Sewage Effluents. Part 1. Removal of Humus. By A. E. J. PETTET, W. F. COLLETT, AND T. H. SUMMERS. *The Surveyor*, **108,** 581 (Sept. 30, 1949).

A study was made by the Water Pollution Research Laboratory on methods of

reducing the quantity of suspended solids in sewage works effluents. Rapid sand filters were tried as well as micro-strainers. Laboratory tests were made to determine suitable types and grades of filtering material.

At the Luton works two rapid pressure filters were set up. Each filter consisted of a vertical cast-iron cylinder 3 ft. high and 2 ft. internal diameter. Filtering material was supported on a perforated plate. A rake which could be moved by hand was provided to help in backwashing. In one filter, sand was used which would pass a 10-mesh (per inch) screen but was retained on 18-mesh. The other filter was filled with an anthracite medium, 10 in. graded between 4- and 8-mesh screens and an upper layer of 14 in. graded between 8- and 18-mesh.

The units were operated in parallel, simulating actual operating conditions as closely as possible. They were operated continuously except for week ends. The rate of application of humus tank effluent was kept at 100 gal. per sq. ft. per hr. Results of operation are summarized as follows: "The content of suspended solids in effluents from the sand filter ranged from 0 to 19 p.p.m. and was nearly always less than 5 p.p.m.; the average reduction in content of suspended solids originally present in humus tank effluent applied to the filter ranged from 67 to 92 per cent. Corresponding ranges in the average percentage reduction of B.O.D. and oxygen absorbed from permanganate by liquids applied to the filter were 47 to 78 and 12 to 29 respectively. Similar but very slightly better results were obtained with the filter containing anthracite."

The filters were backwashed at intervals of about 24 hr. The quantity of filter effluent used for backwashing was about 3 per cent of the volume. The quantity used was 200 to 250 gal. (Imp.) or 63 to 80 gal. per sq. ft. It was applied at a rate of 700 gal. per sq. ft. per hr.

At the start (June, 1948) no difficulty was encountered in operating continuously. In July head losses reached 30 ft. of water during each daily run. During September the filters were cleaned by filling them with humus tank effluent to which had been added sodium hypochlorite solution to produce a concentration of 0.02 per cent free chlorine. After a 1-hr. contact period the filters were again backwashed. The treatment had to be repeated at the end of October. A treatment at the end of November with 0.01 per cent chlorine was not effective. Two treatments were carried out in December with concentrations of 0.02 and 0.03 per cent.

In February an inspection was made and the inside of each filter was found to have a thick coating of a gelatinous material. This material penetrated the sand to a depth of ½ in. in the anthracite filter and ¼ in. in the sand filter. Treatment with 0.05 per cent chlorine with a contact period of 2 hr. appeared to clean the medium fairly well in each filter, but the coating on the walls remained. No further treatments were made from that time on until the filters were taken out of service in May.

Two semi-scale filters each 1 ft. diameter with 15 ft. effective depth were installed at the Finham works of the Coventry Corporation. Design was based on experience gained at the Luton works. Here provision was made for loosening the sand before backwashing by blowing air into the base of the filters. It appears that air scour might prevent progressive blockage of the sand of the sort noted at Luton. No accumulations of gelatinous material were noted in nine month's operation. No treatment with chlorine solution was necessary. Here the sand was found rather more efficient than the anthracite.

A semi-scale micro-strainer was also tested at the Luton works. This device was a woven stainless steel fabric in the form of a drum 2½ ft. diameter and 1 ft. 8½ in. long, open at one end. Two meshes were used—Mark II with 58,000 openings per sq. in., and Mark IIA with 100,000 per sq. in. The nominal wire diameters were 0.06 mm. and 0.045 mm., respectively. The total area of the drum was about 13 sq. ft. of which about 8 sq. ft. were submerged. Humus tank effluent entered the open end. The exposed fabric was sprayed continuously with strained effluent; debris removed was collected in a trough inside the drum. About 7 per cent of the flow of effluent was used for backwashing. Chlorination of the fabric was carried on at intervals of 3 to 8 days to control stoppage of the fabric by organic growths.

Records with Mark II fabric with a drum speed of one revolution in 28

seconds showed reductions in suspended matter of 61 to 73 per cent, and reductions in B.O.D. of 31 to 46 per cent. Better results were obtained with the Mark IIA fabric. During part of the tests with this fabric the speed of the drum was 21 sec. per revolution. The tests covered a period of one year. With the Mark II fabric the maximum rate of flow was 60,000 to 70,000 g.p.d. (Imp.) (312 to 364 gal. per sq. ft. per hr., based on 8 sq. ft.) according to head available. After a larger feed syphon was installed an average rate of 80,000 g.p.d. with Mark IIA fabric was maintained. The speed of rotation was 21 sec. per revolution at these rates.

T. L. HERRICK

City of Seattle—Report on Sewage Disposal. BY A. WOLMAN. (Sept. 25, 1948).

In a report to the City Engineer of Seattle, Wash., it is concluded that Puget Sound, with unusual depths and large tidal variations, has a high capacity for continuing assimilation and conversion of sewage into non-objectionable organic constituents. Further, except immediately adjacent to the City of Seattle, it is in excellent biochemical condition and safe, from a public health standpoint. The City of Seattle has not made logical and effective use of Puget Sound for the adequate disposal of its municipal sewage through failure (a) to extend its discharges into sufficiently deep water at many locations; (b) to maintain discharges continuously at deep water, where originally so planned and constructed, by insufficient capacity of discharge lines, by breaks in outfalls close to shore, by continued additions of storm waters, or by various combinations of these deficiencies; and (c) to develop the most desirable points of discharge.

The sewage must be properly dispersed through multiple outlets at suitable depth and location. In general, there is plenty of dissolved oxygen available; in particular, several smaller situations need cleaning up by installing suitable equipment or reconstruction or relocation of minor outfalls.

The North Trunk sewer, handling half the population, should be extended into 75 ft. of water, with two outlets, and redesigned to carry three times the dry weather flow. Comminution units should be installed and operated, before consideration is given to further removal of grease or floating solids.

Many minor sewers should be extended into deeper water, and details of interception balanced against multiple outlets. No more combined sewers should be built. An industrial waste survey should be made. Performance must be vigilantly checked.

All of the sewers are on the combined basis, with storm overflows. The present population is around 500,000. The water consumption is in excess of 150 g.p.c.d., resulting in weak sewage.

Puget Sound is a large body of water, with depths exceeding 50 to 100 feet, close to shore, with high dilution capacity. Bacterial analyses are cited, showing the decrease with distances from ¼ to 1½ miles from the North Trunk Sewer. The Sound is of excellent sanitary quality (B.O.D. and *B. coli*) below and above Seattle. The dissolved oxygen at key locations in the summer ranged from 6.5 to 9.6 p.p.m.

The waters of Puget Sound can take care of approximately 25,000,000 people, with an 11-ft. tidal range and a 3-p.p.m. D.O. depletion. The major uses of Puget Sound water are for navigation, fish, wild life, bathing, and recreation. Careful review of the standards of the Washington State Pollution Control Commission shows that the only one remotely applicable relates to bathing (that is, the *B. coli* should not exceed 50 per 100 ml. [MPN]). Such a standard is rarely met elsewhere, and is somewhat unrealistic under the circumstances. The report concludes that when the indicated correctives have been applied, the standards of the State Commission will be generally met and recourse to elaborate artificial treatment of Seattle sewage will not be required for many years.

LANGDON PEARSE

Report upon the Treatment of Solid and Liquid Wastes from the Processing of Fresh Fruits and Vegetables in the San Jose Area. BY C. G. HYDE AND G. L. SULLIVAN. 38 pp. mimeo. (Aug. 18, 1949).

This report to the City of San Jose, Calif., on the treatment and disposal of

the solid and liquid wastes from food processing in the area which is or may be tributary to the proposed San Jose sewage treatment works, states that the design of sewage treatment and disposal works cannot proceed until the food industry decides on whether to remove solid wastes by fine screening or not.

It is feasible for the City to design and operate sewage and industrial wastes treatment works and handle all food processing wastes, both liquid and solids. This will increase the plant loading. In any case, all liquid wastes are now and will continue to be discharged into the public sewers. Two conditions are possible—the discharge of liquid after fine screening and the discharge of all wastes after coarse screening to remove trash, tin cans, etc. The program should be determined on the bases of rationality and cost. Estimates in the report show that it is far cheaper for industry to dispose of all its wastes in the public sewers than to dispose of them separately and independently.

Solids may be discharged to the sewers without grinding, but will require enlarged works. An arrangement with industry to cover expenses would extend over at least 15 to 20 years.

Peak processing occurs in September, and 78 per cent of the pack is processed in three months—August, September, and October.

The treatment works should be able to receive 50 m.g.d. Digestion tanks to provide for 50 per cent increase over present flow would receive 104,000 lb. per day if food wastes are fine screened; 261,000 lb. per day if both liquid and solid wastes are discharged to sewers.

In similar situations, oxidation ponds require capacity for 153,000 lb. per day, and 332,000 lb. per day. For digestion of sludge, digester capacity of 700,000 and 1,750,000 cu. ft., respectively, are required. Oxidation ponds require 5,100 and 11,100 acre-ft., respectively.

The estimated cost of facilities for treating the solid wastes of the food processing industry (increased 50 per cent over current) is estimated at $2,154,000. Annual fixed charges and operating costs over a 20-yr. period are estimated at $181,940. The cost per ton of raw fruits and vegetables processed is estimated to average 42¢ per year, ranging from 53 to 28¢. The cost per ton of solid wastes discharged to the sewers and treated at the proposed works averages $1.60 for the 20-yr. period, ranging from $2.00 to $1.10.

Land is estimated at $150.00 per acre.

LANGDON PEARSE

Report of the Special Committee on Pollution Abatement of the Joint Legislative Committee on Interstate Cooperation. State of New York, Legislative Document No. 51. 106 pp. (1949).

New York State in 1949 embarked on a comprehensive pollution abatement program, under legislation enacted by the 1949 session of the legislature. The Special Committee on Pollution Abatement functions within the Joint Legislative Committee on Interstate Cooperation.

The 1949 report sets forth in detail what has happened to New York's waterways as a result of uncontrolled and increasing pollution, and what must be done to restore and maintain these waterways in a state of safe usefulness. In several appendices are included the text of the statute under which a long-range attack on the problem has been launched under authority of the statute-created New York State Water Pollution Control Board, as well as other legislation, to expedite pollution control measures on a local, state, and interstate basis.

The Special Committee on Pollution Abatement, continued by the 1949 session of the legislature, is now studying fiscal and other aspects of the problem.

H. P. ORLAND

Treatment and Disposal of Waste Waters from Decortication of Sisal. By T. W. BRANDON. *East African Agric. Journ.*, **15,** No. 1 (July, 1949).

Waste waters discharged from sisal factories are acidic (pH about 5) and are strongly polluting. Laboratory experiments indicate that the polluting character of the waste waters, previously screened through wire gauze, could not be greatly reduced by sedimentation or mechanical filtration. By treatment with coagulants, the greatest pollution reduction achieved was about 50 per cent, but the liquid remaining after treatment would still be too polluting for discharge to small rivers.

Laboratory experiments on treatment by natural fermentation indicate that this method would not be of great value in reducing the polluting character of the waste waters, as measured by the B.O.D. test. Experiments with the activated-sludge process showed that satisfactory purification could be obtained by treating diluted sisal effluent containing not less than 2 per cent sewage by volume. With a lower concentration of sewage the results were unsatisfactory. Aeration alone, in the absence of activated sludge, caused little reduction in the polluting character of the waste waters.

Large-scale pilot experiments showed that the waste waters could be treated readily by biological filtration, with re-use of effluent for further decortication. By this method of operation, in which the liquid was continuously re-circulated through the system at a high rate, water consumption could be reduced by over 80 per cent, and no waste waters need be discharged. The capital cost of the installation required at a factory processing 100 tons of leaves daily would be about £8,000. Large-scale experiments in which waste waters, previously diluted with filter effluent, were treated by single biological filtration at a rate of 60 g.p.d. per cu. yd. indicated that this method of operation was much less efficient than that in which the liquid was continuously re-circulated through the filter at a high rate with no discharge of liquid from the system.

By adopting a process of dry decortication, with subsequent washing of fibre, the polluting character and the cost of treatment of the waste waters could be reduced by nearly 90 per cent. Recovery of flume tow and extraction of valuable by-products from sisal flesh would be greatly facilitated by dry decortication.

H. P. Orland

Estimation of Grease in Sewage Sludges. By R. J. Stephenson. *The Analyst* (Eng.), **74**, 257 (April, 1949).

The method provides for the dehydration of acidified samples of sludge by the use of magnesium sulfate monohydrate. Anhydrous sodium sulfate was found to be unsatisfactory because with petroleum ether (boiling point 50°–60° C.) the deca-hydrate liberated moisture during the extraction process. The magnesium sulfate monohydrate was prepared by drying the heptahydrate spread in a thin layer at 97° C. overnight. The mixture of sludge and magnesium sulfate becomes hard enough to grind within 30 min. and is then extracted in a Soxhlet apparatus with petroleum ether for 5 hr.

Comparison with the A.P.H.A. standard method gave values similar, although invariably slightly greater. Recovery of grease added to a sludge of known grease content was 98 to 99 per cent. A method of drying acidified sludge on a water bath and finally in an oven at 100° C. prior to extraction gave distinctly lower values than either the proposed method or the A.P.H.A. standard method.

W. W. Sanderson

Iodine from Oil Well Brines. By F. G. Sawyer, M. F. Ohman, and F. E. Lusk. *Industrial and Engineering Chemistry*, **41**, 8, 1547 (Aug., 1949).

Some forms of marine life extract iodine from sea water and are probably responsible for the commercially useful concentrations of iodine found in seaweeds, brine from oil wells, and the Chilean nitrate beds. The iodine concentration in sea water is only about 0.1 p.p.m., whereas that of typical oil field brines may vary from 10 to more than 100 p.p.m. The bromine content is roughly twice that of the iodine.

The iodine recovery process consists of the following steps: skimming waste oil from the brine, coagulation with ferric chloride, acidification, sand filtration, chlorination for liberation of the iodine, stripping of iodine from the brine by means of counter-current air flow in a "blowing out" tower, absorption of the iodine in a packed tower by means of a water solution of hydrogen iodide and sulfuric acid. Water and sulfur dioxide are added continuously to the hydrogen iodide-sulfuric acid absorbing liquor to convert the free iodine absorbed to hydrogen iodide. A portion of the circulating hydrogen iodide-sulfuric acid liquor is bled off and sent to the iodine finishing operations. The iodine-stripped air is recycled to avoid air pollution and evaporative cooling in the stripper. The spent brine leaving the blowing out tower is discharged to a stream. Inasmuch as waste oil has been entirely removed from the brine, iodine recovery eliminates this source of pollution, thus saving the oil

producers the cost of oil removal equipment.

The paper is concluded by a description of the iodine finishing process. Fifteen references and process flow sheet.

PAUL D. HANEY

Electrometric System for Continuous Control of Reduction of Hexavalent Chromium in Plant Wastes. By JAMES L. KELCH AND A. KENNETH GRAHAM. *Plating*, **36**, 10 (Oct., 1949).

This paper describes a practical potentiometric method for the continuous control of the reduction of hexavalent chromium to trivalent chromium with copperas (ferrous sulfate) in the presence of sulfuric acid.

Ferrous sulfate in concentrations up to 12 to 16 oz. per gal., stabilized with sulfuric acid to a pH of 2.0, will reduce hexavalent chromium efficiently, provided enough free acid or equivalent is present to insure a final solution pH of 2.5 or lower. The potential of a platinum-calomel electrode system at which complete reduction of chromic acid in various concentrations is assured is 490 to 500 millivolts.

An installation of a unit for continuous control of the reduction of hexavalent to trivalent chromium in a plant waste consists of a calomel-platinum electrode cell assembly that continuously measures the oxidation potential of the chromic acid waste, a potential amplifier, and a potentiometer recorder. The latter indirectly controls a proportioning valve, which feeds the ferrous sulfate solution from the storage tank into the flowing plant waste. A similar unit is used to adjust continuously the pH of the waste prior to reduction and should be installed on the upstream side of the chromic acid reduction unit at a distance sufficient to insure good acid mixing. The pH control unit is similar to the reduction unit, except that a calomel-glass electrode system is used to control the pH of the waste and the sulfuric acid feed.

Maintenance and control features emphasized include provision of dual control units spaced several hundred feet apart in the waste discharge line, provision of a sump in the waste line to increase the time available for reaction and permit mixing with air, elimination of stray currents, and occasional cleaning of electrodes with concentrated hydrochloric acid. Maintenance of the waste pH below 2.5 helps to minimize fouling of the electrodes. For concentrations of chromic acid up to 200 p.p.m. a setting of 490 to 500 millivolts is satisfactory and insures a small excess of ferrous sulfate. For satisfactory control the pH of the waste must be less than 2.5 prior to reduction and not more than 2.5 after. Large amounts of chromic acid must not be discharged suddenly into the wastes, as even a dual installation will not guarantee complete reduction under extreme load.

PAUL D. HANEY

Report of the Water Pollution Research Board for the Year 1948. Department of Scientific and Industrial Research (Great Britain). 56 pp. (1949).

The report first discusses the softening of water by aeration, with reuse of precipitated calcium carbonate, and the reuse of sea water for cleansing shell fish in connection with chlorination. Next, biological filtration of sewage is considered, with a comparison of methods of operating percolating filters as tested at Minworth, where the effluents from alternating double filtration were found slightly better than effluents from filtration with recirculation. The B.O.D. of the settled sewage applied ranged from 149 to 202 p.p.m. The settled effluents of alternating double filtration contained from 12 to 20 p.p.m. of B.O.D. and 14.8 to 17.3 p.p.m. of nitrite plus nitrate (as parts N). The rate of treatment was 240 Imp. (288 U.S.) g.p.d. per cu. yd. of medium. Experiments at Finham, Coventry, on a stronger settled sewage containing 0.2 to 0.75 per cent by volume of gas liquor, at rates of 120 Imp. (144 U.S.) g.p.d. per cu. yd. of medium, produced effluents containing 16 to 24 p.p.m. of B.O.D., with very little difference between the two types of filters. Other tests at Stivichall, Coventry, indicated that up to 0.25 per cent of gas liquor could be treated, but deterioration occurred at 0.4 per cent of gas liquor, handling up to 60 Imp. (72 U.S.) g.p.d. per cu. yd.

Filter flies have been controlled by a powder containing 6.5 per cent of Gammexane at the rate of 16 lb. per acre. Apparently fish are affected by concentrations of 0.1 p.p.m. or more Gammexane (pure gamma isomer). However, if a trickling filter is treated with Gammexane at a rate not exceeding 1 lb. of the gamma

isomer per acre at each application, the effluent is not toxic to fish.

Sewage effluent was filtered through sand and through crushed anthracite to remove humus, following sedimentation. The filters were backwashed with effluent.

Laboratory tests were made to ascertain the effect of chlorine on the destruction and after-growth of bacteria in sewage and sewage effluents. The effects observed were that the percentage of bacteria destroyed was larger as the initial concentration of chlorine was increased, and the destruction of bacteria was followed by growths of survivors, eventually exceeding those of the raw sewage.

Pure cultures of the bacteria surviving chlorination and responsible for after-growth showed, out of 37 such cultures, 25 were gram-negative rods, 5 were gram-positive rods, and 2 were gram-positive cocci. The effect of chlorination on bacterial counts of liquids containing small amounts of gas liquor or thiocyanate was also found more pronounced than if no gas liquor was added.

The industrial wastes waters discussed are those of processing sisal, coffee, grain (washing of wheat), and manufacture of cider, also acid waste waters from steel pickling (reference being made to upward filtration through small particles of crushed limestone; cf. Gehm, H. W., THIS JOURNAL, **16**, 1, 104; 1944: and Reidl, A. L., *Chem. Eng.*, **54**, 100; 1947). Tests also were made to remove dissolved iron and are being continued. Waste waters containing cyanide may be treated by chlorine in alkaline solution.

The effect of discharge of alkaline sludge to the estuary of the River Mersey was examined to determine if it was permissible for an industry to discharge about 8.25 Imp. m.g.d. containing 500 tons of dry solids. The tidal basin was examined and the rate of sedimentation of the Mersey mud studied. Apparently, carbonation of the sludge would remove its accelerating effect on the rate of deposition of Mersey mud.

No conclusions are given.

LANGDON PEARSE

Methods of Surveying Steel Plant Wastes. BY A. H. ARBOGAST AND J. E. GOLD. *Iron and Steel Engr.*, **26**, 80 (Dec., 1949).

The authors point out that industrial waste work requires an adequate laboratory, and personnel that understands the various methods of analysis and measurement of fluids, as well as conventional waste treatment operations and their interrelationships. Where suitable personnel is not available in the plant, the advice of a recognized consulting engineer should be sought. The importance of accurately determining concentrations, and of collecting representative samples in proportion to flow rate, is emphasized.

Steel plant wastes are classified in the following categories: sand and silt from quarries and ore preparation plants; waste waters from blast furnaces, including gas washer waters, blowing engine lubricants, and hot cooling water; condensate containing oil or tar, and gas scrubber water, from open hearths; water containing oil, grease and scale, pickle liquor, galvanizing and electroplating liquors, cylinder oil, paint solvents and drying oils, from mill operations; soluble oils, lubricating oil, and degreasing solvents, from machine shops; steam condensate containing oil, grease and scale, from forge shops; and condensate and cooling water containing tar acids and other impurities, caustic desulfurizer liquors, iron oxide from desulfurizer boxes, and absorption oil residues, from by-product coke plants.

When the plant survey and research studies are completed, a systematic program should be formulated to establish a reasonably accurate schedule for construction and subsequent operation of facilities.

More or less conventional methods for conveying, treating and settling various waste waters are reviewed, including practices at Bethlehem steel.

This paper was discussed at length by H. G. Knox, Technical Advisor, Pennsylvania Sanitary Water Board, who reviewed the efforts of the Board to establish waste treatment standards by industry classes. The Board believes that a common set of effluent standards to govern all industry would be impractical. Standards that have been prepared for the milk, and the oil and gas well industries, are about ready for promulgation. Plans for standards for tanning, paper manufacture, and steel pickling, are well advanced.

Mr. Knox pointed to specific savings that had been effected by preventing useful materials from becoming wastes in the first place. He emphasized the im-

portance of including a cost analysis in any study of industrial waste disposal, and welcomed consultation with the Bureau of Engineering on waste disposal problems.

RICHARD D. HOAK

Mechanical Filtration of Sewage Effluents. *The Surveyor*, **108**, 661 (Nov. 4, 1949).

In the discussion of a paper of the same name, which appeared in the Sept. 30 issue of *The Surveyor* (abstracted in this issue of THIS JOURNAL, p. 579), it was pointed out that there was a danger of anerobic conditions developing in a rapid sand filter used for the treatment of settled effluents. Such conditions did not develop in the closed semi-scale filters used in the tests; although the dissolved oxygen was absorbed, septic conditions did not develop. It is felt that open filters would be less apt to develop such a condition. There was little chance for loss of oxygen in the case of the micro-strainer.

The suggestion had been made that rapid filters or micro-strainers might be used instead of humus tanks following trickling filters. It is felt that the rates of filtration used in the tests could be maintained, but that more backwashing would be required and the size of the installation would have to be increased, with either micro-strainers or rapid filters. The greater amounts of wash water and the higher concentrations of solids might require an increase in the volume of the primary settling tanks.

T. L. HERRICK

Utilization of Organic Domestic Wastes. BY CHARLES E. BURKE. *The Surveyor*, **108**, 629 (Oct. 21, 1949).

During the past few years much has been said concerning the composting of household refuse with sewage sludge. It has been reported that the application of pulverized refuse has a beneficial effect. On the other hand, reports on research work and field experiments have but faintly praised such composted materials. It is not the intent here to discuss the fertilizing value of household refuse or sewage sludge, or of the composts of these materials, but to accept the fact that they have a definite value when applied to the land. It is assumed that all inorganic matter is removed from household refuse before it is used for composting.

Studies as to the probable cost of the disposal of refuse from a population of 500,000 were made, based on the information continued in a 1942 paper by C. C. J. Bullough (facilities for refuse separation, pulverizers, composting bays, and maturing grounds; population, 50,000; refuse, 40 to 50 tons per day; and sludge available, 36 tons per day at 95 per cent moisture).

Plant requirements were worked out and estimates of costs and annual revenue were made for the composting of the refuse from a population of 557,640. The estimated amounts of refuse and sewage sludge were 140,000 tons and 6,022 tons (dry basis) per year, respectively. The plant facilities in the layout included receiving hoppers, separation plant, pulverizers, composting bays, and maturing grounds. The area of the composting bays was such that the material could be retained there for a minimum of 7 days plus time for turning and removal, or an estimated total time of 10 days. A period of 22 weeks was provided in the maturing grounds. Annual costs were estimated at $226,348 not including taxes, administration, or any cost in connection with the acquisition of land. Estimated income is as follows:

Material	Tons	Price	Amount
Dust and fine ash	59,920	$0.20	$11,984
Cinders	15,260	0.50	7,628
Paper	6,160	28.00	172,480
Ferrous metal	3,360	2.30	7,728
Non-ferrous metal	28	200.00	5,600
Rags	350	96.00	33,600
Bottles	574	24.00	13,776
Cullet	308	3.00	924
Compost	60,062	1.80	108,108
Total	146,022		$361,828

Thus, the excess of income over costs is $135,480.

If the aim were to produce the maximum amount of compost by adding dust, paper, and rags the total quantity would be 126,492 tons and the estimated income would be $260,100 (based on the same unit price for compost as used before). The annual costs would be higher, as additional plant facilities and composting area would be required. Revised estimated annual costs are $237,324, or $22,776 less than the estimated income.

Composting may be practical in rural areas where ample space is available at the sewage treatment works. Tonnages are such that they can be handled with simple mechanical aids and the output usually can be sold to nearby farmers. In larger communities difficulties may be encountered in disposing of the output continuously. Prolonged storage is not economical, and the raw wastes must be accepted whether or not there is a market for the output.

T. L. Herrick

Utilization of Organic Domestic Wastes. *The Surveyor*, **108**, 655 (Oct. 28, 1949).

This article is a report of the discussions of a paper of the same name which appeared in the Oct. 21st issue of *The Surveyor*. The first discusser expressed the opinion that it was a failure not to conserve all organic wastes and return them to the soil. At times other methods of disposal (such as barging to sea) will be more economical, but expedience should not be the deciding factor. It did not appear practical to give up the income from the sale of paper by processing it with the composting material. It was suggested that provision be made for adding grasses from the roadsides and sawdust in the compost.

Another discusser called attention to the fact that the author had used figures based on Bullough's paper (1942) and that conditions had changed in the succeeding years. Experience at Maidenhead showed that the revenue from the sale of compost did not pay for the costs of production. However, the method was still a practical method of handling the material if it did not entail greater costs than other methods of disposal. It is a mistake to give the idea that the method would provide a saving in the taxes. He thought that the cost of composting would be about the same as for controlled dumping of refuse and disposal of sludge by normal methods. It appeared that there was still a great difference of opinion on the value of compost.

T. L. Herrick

Utilization of Organic Domestic Wastes. *The Surveyor*, **108**, 665 (Nov. 4, 1949).

In this continuation of the discussions of the paper of the same name, it was pointed out that composting had been carried on at Maidenhead for 13 years, and for 12 years at Leatherhead. It had been used at a number of small communities in South Africa, and also in New Zealand and Central America. Another speaker felt that less trouble was entailed by applying the sludge directly to the land. Still another expressed the opinion that "(1) it was more or less a messy product, and (2) it had too many uninformed disciples." Many who had tried to get firsthand information on the subject had not been very successful.

T. L. Herrick

Liquor Effluents and Ammonia Committee. By C. F. Botley. *Gas World* (London), **130**, 1927 (Dec. 3, 1949).

Increased sales of gas has led to greatly increased production of gas liquor and liquor effluent, and many gas works must pay heavy charges to sewage authorities for removal. Many small works make little or no effort to deal with ammonia liquor. Installation of ammonia recovery plants at small works is not usually practical, but some improvement can be made by more careful control of the condensing, scrubbing, and purifying plant. Electrostatic detarring, applicable to both old and new plants, results in a liquor of greatly reduced toxicity.

Richard D. Hoak

Effluent Disposal. *Gas World* (London), **130**, 1927 (Dec. 3, 1949).

Where possible, the best solution is for the gas works to make a controlled discharge to sewers of liquor containing the minimum quantity of thiocyanate and polyhydric phenols, and from which free ammonia, sulfide, and cyanide have been removed by distillation. A large number of processes has been devised for removal of monohydric phenol, although it is uncertain whether this operation is profitable. One plant, using light creosote as a solvent for phenol, has been operating profitably, but it was built before present high construction costs.

Richard D. Hoak

Standards for Trade Effluents? *Chem. Trade Journ.* (London), **125**, 723 (Dec. 16, 1949).

Although in certain authorities and local Acts effluents have been required to conform to specified standards, no standard of

quality has generally been defined in the various Acts dealing with prevention of pollution of rivers. The Rivers Pollution Subcommittee now reports that such standards are not only desirable but practicable. The subcommittee is supported in its view by many witnesses. It did not itself attempt to fix any standards, but suggests that the first step would be to agree on tests that would measure some general property, such as B.O.D. or toxicity to fish. The next step would be to prescribe standards applicable to any rivers or streams, or portions of them, at the River Board's discretion.

RICHARD D. HOAK

Water Pollution Abatement Manual for Insoluble and Undissolved Substances, Manual W-2. Manufacturing Chemists' Association, Washington, D. C. 12 pp. (Aug., 1949).

This manual, prepared by the Water Pollution Abatement Committee, is the Association's second publication on the subject of water pollution abatement. Topics covered in the seven sections of this manual are: Effect on receiving waters, permissible concentrations, removal of solids from wastes, sludge digestion, sludge dewatering, sludge disposal, and equipment sources.

The section on solids removal is the most extensive, being subdivided into brief discussions on screening, disposal of screenings, sedimentation and clarification, lagoons, detritus tanks, sedimentation tanks, flotation, and filtering.

PAUL D. HANEY

Two Stage Filtration vs. Single Stage. By C. J. DEKEMA AND P. R. KRIGE. *Public Health* (So. Africa), **13**, 280 (Sept., 1949), and 317 (Oct., 1949).

In January, 1939, tests were started at the Rondeblut sewage works in a pilot plant which provided two-stage filtration of settled sewage. At the end of 1941 definite conclusions were drawn and results were published in April, 1942. The conclusions were that "a double filtration system such as the one described represents an advance in sewage works practice. A double filtration process employing two 12-ft. deep, enclosed, artificially ventilated filters and two humus tanks is likely to show an increase in performance of 40 per cent over a normal system employing single filtration."

While the tests were under way the main filter bank for the Rondeblut works was being extended and features used in the pilot plant were incorporated. In September, 1943, large-scale tests were started. For these tests 5 of the 8 filters were selected. They were:

Number	Diam. (ft.)	Depth (ft.)	Volume (cu. yd.)	Media					
				Bottom		Middle		Top	
				Depth (ft.)	Size (in.)	Depth (ft.)	Size (in.)	Depth (ft.)	Size (in.)
1	75	12	1,965	1¼	4 to 6	9	1 to 1½	1¾	2 to 2½
2	75	14	2,200	1	4 to 6	12	1½ to 2	1	2 to 2½
6, 7, 8	75	14	2,200	1	4 to 6	12	1½ to 2	1	2 to 2½

All filters are enclosed and ventilated by forced draft downward. Filters 6 and 7 were operated as two-stage filters, with an intermediate humus tank. Results for the period September, 1943, to December, 1944, are shown in the following table:

	No. 1 Single	No. 2 Single	No. 8 Single	No. 6 Primary	No. 7 Secondary
Dosing rate (g.p.d./cu. yd.)	189	198	198	535	529
Absolute rate (g.p.d./cu. yd.)	196	204	204	554	546
Influent B.O.D. (p.p.m.)	276	276	276	276	—
Effluent B.O.D. (p.p.m.)	24	16	17	73	22
B.O.D. removed (p.p.m.)	252	260	259	—	254
B.O.D. removed (lb./day/cu. yd.)	0.493	0.530	0.529	—	0.693
Air (c.f.m./cu. yd.)	—[1]	1.36	1.41	1.59	1.50

[1] Not metered.

It appears that the two-stage filters operated in fixed sequence show at least a 30 per cent improvement in performance over the single-stage filters.

During the period of the tests ponding was slight and spasmodic on the single-stage filters and on the secondary filter of the two-stage unit; it was troublesome on the primary filter at fairly regular intervals. The exhaust air from the single-stage filters and from the secondary had an earthy odor, not objectionable. The odor of the air from the first-stage was very unpleasant.

The sludge from the humus tank following the primary-stage filter was black, with a bad odor, and requires further treatment, such as digestion along with raw sludge. Thus, additional capacity is necessary with stage filtration over what would be required with single-stage filters. It is felt, however, that removal of humus sludge between stages gives two-stage filters the advantage over single-stage.

Tests were also carried on with the two-stage unit in which reversals of flow were made at varying intervals. Two very gradual reversals were made in which the time for the complete reversal was 40 days in one case and 25 days in the other. Slight but positive improvement in the B.O.D. of the secondary effluent was noted. Further tests on reversals were made with varying intervals and times required for the reversals. Daily instantaneous reversals were made for a period of about 40 days. The authors feel confident that, whereas the improvement of two-stage in fixed sequence over single-stage is of the order of 30 per cent, the improvement (or extra treating capacity) to be obtained with two-stage filtration incorporating frequent reversal, is likely to exceed 50 per cent.

T. L. HERRICK

The Agricultural Use of Sewage. BY WILHELM MULLER. *Wasser und Boden* (Germany), p. 124 (1949).

During recent years the agricultural use of sewage has often been discussed in Germany without finality being reached on this important question. Public health requires a hygienic sewage disposal, but the problem cannot be solved alone by local authorities. It is a task for the State organization, especially in densely settled countries.

Water conservation has become more important. Use of water has to be regulated. Within this water planning sewage has its own part. In particular the agricultural use of sewage by different technical means may appreciably increase the productivity of a country. For this purpose sewage must be fully treated and freed of pathogenic organisms.

The humus matter and the manure value of sewage should be used in agriculture to compensate for the organic matter exported from the country as food. Sewage disposal into the ocean only "manures" the seawater. Only such volume of treated sewage should be discharged into rivers as is necessary to manure the rivers for fishing industries.

W. MULLER

Disposal of Plating Room Wastes. BY B. F. DODGE AND D. C. REAMS. American Electroplater's Society. 48 pp. $1.00 (1949).

This critical review of the literature pertaining to the disposal of waste cyanide solutions was sponsored by the American Electroplater's Society and included consideration of all proposed methods of cyanide waste treatment, whether used or not. The review also included articles on the effects of cyanides on streams and sewage treatment plants.

The authors' conclusions are briefly summarized as follows:

It appears from published results that concentrations of less than 0.01 to 0.02 p.p.m. of CN in a stream would be acceptable in most cases, and that in some cases concentrations of 0.5 p.p.m. or more might be tolerated. The permissible cyanide content of sewage may be as much as 3 p.p.m. and the amount in the waste higher, depending on the dilution.

Cyanogen compounds, such as the complex cyanides, cyanates, and thiocyanates, are much less toxic than the cyanide ion and this fact is utilized in several treatment processes.

Segregation of wastes prior to treatment is desirable. Separating concentrates from dilute wastes may allow discharge of the latter without treatment or after simpler treatment than would be required of the mixture.

Dilution, although the simplest and most desirable method of disposal from the standpoint of the plater, has only limited application due to the high toxicity of the cyanide ion. In addition, this method

requires careful control of the release of the waste in order to avoid temporary locally high concentrations. This control is not easy to insure under all conditions.

Evaporation of concentrated wastes may have merit at small plants. Acidification and volatilization of the hydrogen cyanide as a gas is now practiced at several large plants. One method of eliminating entirely any question of the toxic effect of hydrogen cyanide in the discharged gases is to burn them. Recovery of the cyanide from the air might be accomplished by adsorption. The conversion of the cyanide ion to insoluble cyanides of such metals as zinc, copper, or lead is a method of treatment that has been laboratory tested, but which holds little promise. The precipitating agents are relatively expensive and the removal of cyanide is not very complete. The formation of insoluble iron ferro- or ferricyanides by treatment of cyanide wastes with lime and iron salts is practiced extensively abroad. Much study needs to be given to this process before its true worth can be determined. The literature contains conflicting statements as to its value.

The oxidation of cyanide to less toxic cyanate at pH 8.5 or above is coming into wide use in the United States. Chlorine is probably the most satisfactory and cheapest oxidizing agent. Usual practice is to destroy the cyanate also by an excess of chlorine. The end products are then carbon dioxide and nitrogen. This method appears to be applicable to nearly all types of cyanide wastes. When chlorine is the oxidizing agent it does not appear to be satisfactory for silver plating wastes because of difficulty in recovering the silver. Electrolytic oxidation of the cyanide with plating out of the metals has been used; its application is probably limited to concentrated wastes. The use of polysulfides to form less toxic thiocyanates has been tested and found to be not very satisfactory. The reaction of formaldehyde with hydrogen cyanide and alkali cyanides has received some consideration, but published data are too incomplete to form a basis for evaluation. Little work has been done on the ion exchange treatment method. This method is essentially a concentrating process.

Plating waste problems are complicated by the great variation in the size of the plants producing the waste. Few plants have accumulated data on the composition and volume of the wastes, both of which are quite variable. Where there is great variation, batch treatment appears to be best. An important fact is that there are often two types of waste, the strong spent baths and the dilute rinse waters. The applicable treatment methods may be entirely different.

It is seldom economically feasible to attempt recovery of valuable materials. An important exception is in connection with wastes from silver plating.

This literature review indicates a great dearth of quantitative data on proposed and operating processes. Progress in the future will probably be in the direction of improvement of known processes.

The bibliography contains 86 references.

PAUL D. HANEY

Cyanide Waste Disposal. BY ROGER WILLIAMS, JR. *Chem. Eng.*, **56**, 9, 97 (Sept., 1949).

This paper presents a description of the National Carbon Company's cyanide waste disposal plant located at St. Albans, Vt. The operation of producing finished flashlights from sheet brass involves several chemicals creating difficult disposal problems. Cyanide wastes from electroplating operations posed the greatest problem. These wastes are treated prior to disposal to the city sewer by means of chlorine and caustic for cyanide removal, neutralization, and precipitation of the heavy metals. Waste disposal equipment consists of chemical feeding, agitating, storage, and sedimentation devices. The final effluent is clear, free of cyanides, mildly alkaline, and contains 1 to 3 p.p.m. of free chlorine. Sludge is removed from the settling tanks by pumping and is discharged to an earth lagoon. Total sludge averages about 2,200 cu. ft. per month.

The process is under careful laboratory control and the laboratory maintains a small aquarium in which goldfish are kept in a mixture of city water and treated waste proportioned so that dilution conditions are more severe than in the stream into which the plant wastes are finally discharged.

Treatment of strong acid wastes is simplified because of segregation practice. In the absence of cyanide, acids are easily treated by batch neutralization with caustic soda.

PAUL D. HANEY

Book Review

Handbook of Chemistry. By N. A. Lange. Handbook Publishers, Inc., Sandusky, Ohio. Seventh Edition, 1949. $7.00. 1920 pp.

The 1920-page seventh edition of this excellent reference work contains not only a thorough revision of materials previously presented, but also a considerable number of tables not in the previous edition. Of particular value as a source of chemical data, the volume is equally valuable for its physical data used in laboratory work and manufacturing. As a concession to the necessities of holding size and cost within the bounds of reality, much of the basic mathematical data contained in an appendix to all previous editions has been eliminated, and published in a separately bound volume.

Tables extended or completely rewritten include:

Periodic Chart of the Elements
Description of the Elements
Table of Isotopes
Plastics and Synthetic Rubbers
Composition and Use of Foods
Typical Analyses of Various Public Water Supplies
Corrosion and Heat Resistant Alloys
Commonly Used Ceramic Materials
Index of Refraction of Liquids
Single Electrode Potentials
Composition and E.m.f. of Voltaic Cells
Electrometric Determination of Hydrogen Ion Concentration
True Capacity of Glass Vessels
Standard Volumetric (Titrimetric) Solutions
Specific Gravity of Aqueous Ethyl Alcohol
Vapor Pressures of Various Substances
Properties of Saturated Ammonia
Heat of Vaporization of Compounds
Viscosity of Water
Standard Letter Symbols and Abbreviations
Gas Constant
Definitions of Chemical, Physical, and Pharmaceutical Terms
Photographic Emulsion Speed Ratings
Formulas and Properties of Denatured Alcohols

Tables not in the previous edition and now offered for the first time include:

Abundance of the Elements
Glyceride Content of Drying Oils
Properties of Hormones
A.S.T.M. Classification of Coals by Rank
Formulas for Calculating Mineral-Free B.t.u. and Fixed Carbon
Density of Fuming Sulfuric Acid Solutions
Dielectric Constants
Dipole Moments
Mass of Water in Saturated Air
Partial Pressures of Aqueous Ammonia Solutions
Kopp's Rule for Calculating Specific Heat
Logarithms of Equilibrium Constants
Viscosity of Aqueous Sucrose Solutions
Viscosity of Aqueous Ethyl Alcohol Solutions

The detailed and excellently cross-referenced 26-page index further enhances the value of this excellent compilation of essential data.

H. P. Orland

Professional Opportunity

SANITARY ENGINEER—SELFRIDGE AIR FORCE BASE, MICH.

Position: Sanitary Engineer, GS–11, at Selfridge Air Force Base, Mich.

Salary: $5,400 per annum.

Required Qualifications: Applicants must have completed a standard professional engineering curriculum leading to a Bachelor's Degree in a college or university of recognized standing; or they must show that they have had at least 4 years of successful and progressive technical engineering experience of such a nature as to enable them to perform successfully at the professional level; or any time equivalent combination of education and experience. In addition to the minimum qualifications indicated above, applicants must show an additional 3 years of progressive professional engineering experience, including at least 1 year of difficult and important work in one of the branches of engineering equivalent in grade level to that required of GS–9 engineers.

Examination: The examination will consist of a rating of education and experience. The usual veteran's preference will be allowed in accordance with Civil Service regulations.

Closing Date for Applications: Applications will be accepted until further notice.

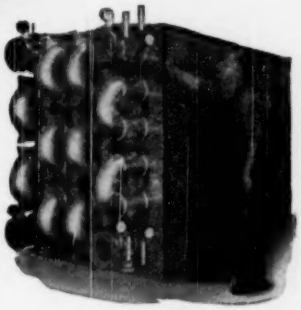
Application: Interested applicants should transmit completed U. S. Civil Service Standard Form 57, obtainable at any U. S. Post Office or Civil Service office, to Civilian Personnel Office, Selfridge Air Force Base, Mich.

Raw sludge is pre-heated by a No. 629 P.F.T. Heat Exchanger before being pumped to the five digesters at the Madison, Wisc., sewage treatment plant.

Waste heat from engines, utilizing sludge gas as fuel, pre-heats the sludge. Engine jacket water is circulated through the annular space between the 8" shell pipe and the 6" sludge tube. P.F.T. Safety Gasket Rings positively prevent contamination of engine jacket water.

The sludge tubes have specially designed sweep return bends which amply provide for flow of sludge with minimum of frictional loss. Return bends and all pipes are easily removable for cleaning.

This installation is part of a plant expansion program. By providing adequate recirculation of the sludge, more effective use can be made of the existing digestion tanks. This is another example of the application of P.F.T. advanced design to more effectively utilize all existing structures.



P.F.T. Heat Exchanger built for Madison Metropolitan Sewage District. Greeley & Hansen, Engineers.

ENGINE COOLING WATER
SLUDGE

P.F.T. PIONEER IN SLUDGE TEMPERATURE CONTROL. HAS THE "KNOW HOW" BASED ON NUMEROUS INSTALLATIONS

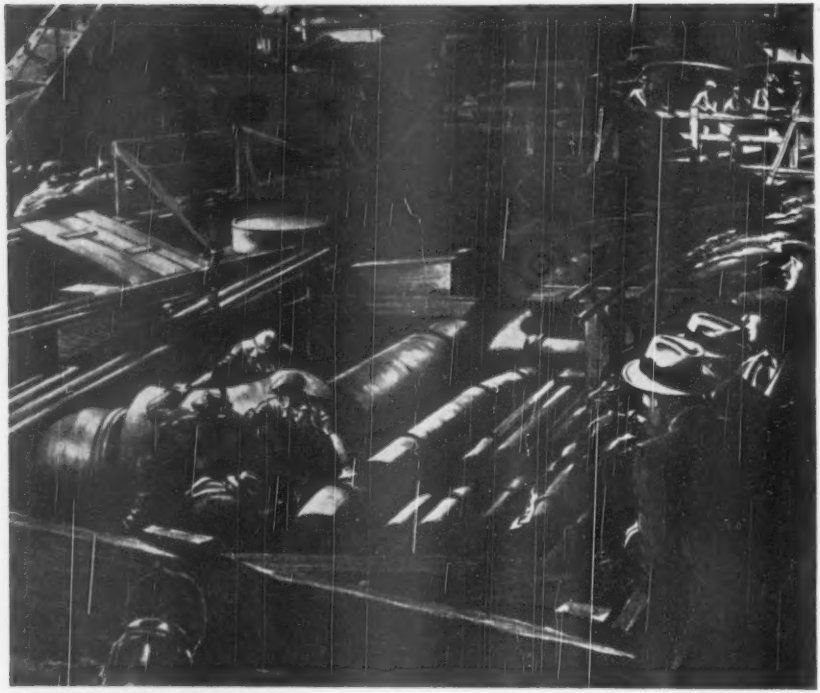
P.F.T.

PACIFIC FLUSH TANK CO.

SEWAGE TREATMENT EQUIPMENT EXCLUSIVELY SINCE 1893

4241 RAVENSWOOD AVENUE CHICAGO 13, ILLINOIS

NEW YORK • LOS ANGELES • SAN FRANCISCO • CHARLOTTE, N. C. • DENVER • TORONTO



Lithographed on stone by Edward A. Wilson

Take the lid off a busy street in any sizeable city! What will you find? A maze of mains—water, gas, and sewer mains—many of them cast iron mains—some of them in service for generations. Traffic shock, earth settlement, or earth disturbance by other utilities, are withstood by cast iron pipe because of its shock strength, beam strength, and crushing strength. These strength factors, plus inherent resistance to corrosion, result in long life and economy. U. S. Cast Iron Pipe and Fittings, produced under modern quality-controls, are readily available in sizes to meet the normal requirements of any community. United States Pipe and Foundry Company, General Offices: Burlington, New Jersey. Plants and Sales Offices throughout U. S. A.

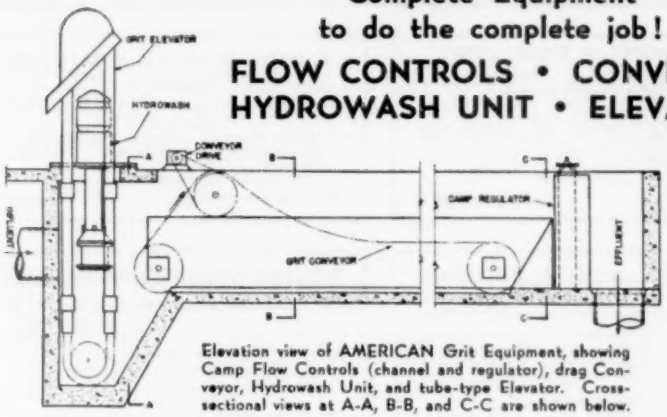
U.S.
cast iron
PIPE
FOR WATER, GAS, SEWERAGE AND INDUSTRIAL SERVICE

REMOVE GRIT

EASILY...THOROUGHLY...AT LOW COST!

Complete Equipment to do the complete job!

FLOW CONTROLS • CONVEYOR
HYDROWASH UNIT • ELEVATOR



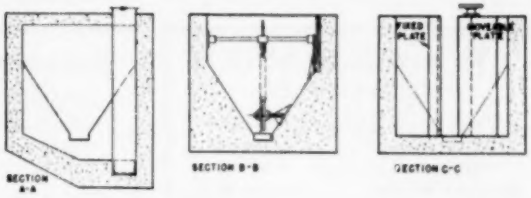
Elevation view of AMERICAN Grit Equipment, showing Camp Flow Controls (channel and regulator), drag Conveyor, Hydrowash Unit, and tube-type Elevator. Cross-sectional views at A-A, B-B, and C-C are shown below.

PROVIDES CONSTANT OPTIMUM VELOCITY

POSITIVE ADJUSTMENT FOR VARYING FLOWS

HYDRO-DYNAMIC WASHING

AUTOMATIC DRAINING AND REMOVAL



FLOW CONTROLS—exclusive Camp Control Section and Regulator maintain constant optimum velocity for effective grit settling, regardless of rate of flow through plant. Velocity can be easily and instantly adjusted to meet changing conditions.

CONVEYOR—single strand, continuous drag type carries grit from channel to hopper for washing and removal.

HYDROWASH UNIT—washes grit free of organic matter by producing a turbulent downflow recirculation of liquor in grit hopper.

ELEVATOR—totally enclosed, tube type, for slow and continuous removal of washed grit from the hopper. Grit drains as it is being elevated through the tube.

Write for Bulletin No. 249A

We have just issued Technical Supplement "CR", containing complete design data on the AMERICAN CAMP GRIT CHANNEL and REGULATOR. Available on request with Bulletin 249A.

AMERICAN WELL WORKS

IN OUR 82ND YEAR
110 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH - ENGINEERING - MANUFACTURING

Offices: Chicago • New York • Cleveland • Cincinnati • Kansas City • Sales Representatives throughout the World

DIRECTORY OF ENGINEERS

(Continued to page 24)

ALBRIGHT & FRIEL, INC.
FRANCIS S. FRIEL
Consulting Engineers
WATER, SEWAGE AND INDUSTRIAL WASTE PROBLEMS
AIRFIELDS, REFUSE INCINERATORS
INDUSTRIAL BUILDINGS
CITY PLANNING VALUATIONS
REPORTS LABORATORY
Suite 1509-15
121 S. Broad St. PHILADELPHIA 7

ALVORD, BURDICK & HOWSON
Engineers
Charles B. Burdick Louis R. Howson
Donald H. Maxwell
Water Works, Water Purification, Flood Relief, Sewerage, Sewage Disposal, Drainage, Appraisals, Power Generation
Civic Opera Building Chicago

MICHAEL BAKER, JR., Inc.
The Baker Engineers
Civil Engineers, Planners, and Surveyors
Municipal Engineers—Airport Design—Sewage Disposal Systems—Water Works Design and Operation—Surveys and Maps—City Planning—Highway Design—Construction Surveys—Pipe Line Surveys
Home Office: Rochester, Pa.
Branch Offices: Jackson, Miss. Harrisburg, Pa.

BAXTER, NELSON & WOODMAN
Civil and Sanitary Engineers
Water Supplies Water Treatment
Sewer Systems Sewage Treatment
Industrial Waste Treatment
Investigations
P. O. Box 67 Crystal Lake, Illinois

W. H. & L. D. BETZ
Consulting Engineers
Industrial Waste
Industrial Water
Analysis Design
Investigations Operation
Gillingham & Worth Sts. Philadelphia 24, Pa.

Don't be fourth . . .
to send in your professional card for listing in The DIRECTORY OF ENGINEERS. There are just three more available spaces remaining for card listing among these outstanding specialists.

BLACK & VEATCH
Consulting Engineers
SEWAGE - WATER - ELECTRICITY - INDUSTRY
Reports, Design, Supervision of Construction
Investigations, Valuation and Rates
4706 Broadway Kansas City 2, Missouri

CLINTON L. BOGERT ASSOCIATES
Consulting Engineers
CLINTON L. BOGERT IVAN L. BOGERT
J. M. M. GREIG ROBERT A. LINCOLN
DONALD M. DITMARS ARTHUR P. ACKERMAN
Water and Sewage Works
Refuse Disposal Industrial Wastes
Drainage Flood Control
624 Madison Ave, New York 22, N. Y.

BOWE, ALBERTSON & ASSOCIATES
Engineers
Sewerage—Sewage Treatment
Water Supply—Purification
Refuse Disposal—Analyses
Municipal —Industrial Projects
Valuations—Reports—Designs
110 William Street New York 7, N. Y.

Take advantage of the services of these outstanding consultants!

BUCK, SEIFERT AND JOST
Consulting Engineers
(FORMERLY NICHOLAS S. HILL ASSOCIATES)
Specializing in Sewerage and Sewage Disposal, Water Supply and Water Purification, Valuations and Reports
Chemical and Biological Laboratories
112 East 19th Street — New York 3, N. Y.

BURGESS & NIPLE
Civil and Sanitary Engineers
Established 1908
Water supply, treatment and distribution
Sewage and industrial wastes disposal
Investigations, reports, appraisals, rates
Airports Municipal Engineering Supervision
584 E. Broad Street — Columbus 15, Ohio

BURNS & McDONNELL
Consulting and Designing Engineers
Kansas City, Mo. P.O. Box 7088
Cleveland, Ohio 1404 E. 9th St.

CAMP, DRESSER and McKEE
Consulting Engineers
Water Works and Water Treatment
Sewerage and Sewage Treatment
Municipal and Industrial Wastes
Investigations and Reports
Design and Supervision
Research and Development
Flood Control
6 Beacon St. — Boston 8, Mass.

CAPITOL ENGINEERING CORPORATION
Engineers—Constructors—Management
SEWAGE SYSTEMS — WATER WORKS
Designs and Surveys — Roads and Streets
Planning — Airports
Bridges — Dams
Executive Offices
DILLSBURG, PENNSYLVANIA

THE CHESTER ENGINEERS
Water Supply and Purification, Sewerage Systems, Sewage and Industrial Waste Treatment, Power Development and Applications, Investigations and Reports, Valuations and Rates.
210 E. Park Way at Sandusky, Pittsburgh 12, Pa.

CONSOER, TOWNSEND & ASSOCIATES
Water Supply—Sewerage—Flood Control & Drainage—Bridges—Ornamental Street Lighting—Paving—Light and Power Plants. Appraisals.
351 East Ohio St. — Chicago 11, Ill.

OSCAR CORSON
Consulting Engineer
Sewage and Industrial Waste Problems
Drainage—Water Supply—Airfields
Plans—Supervision—Surveys
902 Highland Avenue — Ambler, Pa.

Damon & Foster
Consulting Civil Engineers and Surveyors
Sewerage, Sewage Disposal, Water Supply, Surveys, Land Subdivision, City and Town Planning, Reports, Design, Supervision
Sharon Hill, Pennsylvania

FREDERICK H. DECHANT
ENGINEER
Chairman of the Board, Frederic R. Harris Inc.
Water Works, Industrial Wastes, Sewerage, Recovery Processes, Hydraulic Works, Gas Plants
Philadelphia: Fidelity Phila. Trust Bldg.
New York: 27 William St.

DE LEUW, CATHER & COMPANY
Water Supply — Sewerage
Railroads — Highways
Grade Separations—Bridges—Subways
Local Transportation
Investigations — Reports — Appraisals
Plans and Supervision of Construction
150 North Wacker Drive — Chicago 6
605 Colorado Bldg. — Washington 5

FAY, SPOFFORD & THORNDIKE
ENGINEERS
CHARLES M. SPOFFORD — RALPH W. HORNE
JOHN AYER — WILLIAM L. HYLAND
BION A. BOWMAN — FRANK L. LINCOLN
CARROLL A. FARWELL — HOWARD J. WILLIAMS
Water Supply and Distribution—Drainage
Sewerage and Sewage Treatment—Airports
Investigations and Reports — Designs
Supervision of Construction — Valuations
Boston — New York

It pays to secure competent and experienced engineering advice!

EDWARD A. FULTON
Consulting Engineers
Investigations, Reports, Valuations, Design and Construction—Water Supply and Purification Plants; Sewerage and Sewage Treatment Works; Municipal Paving and Power Developments; Dams and Flood Control
3299 Brown Road — Saint Louis 14, Missouri

GANNETT FLEMING CORDDRY & CARPENTER, INC.
ENGINEERS
Water Works—Sewage
Industrial Waste & Garbage Disposal
Roads—Airports—Bridges & Flood Control
Town Planning Appraisals
Investigations & Reports
Harrisburg, Pa. — New York, N. Y.
Scranton, Pa. — Pittsburgh, Pa.

GILBERT ASSOCIATES, INC.
Engineers and Consultants
Water Supply and Purification
Sewage and Industrial Waste Treatment
Chemical Laboratory Service
Investigations and Reports
New York Houston — READING, PA. — Washington Philadelphia

IVAN M. GLACE
Consulting Sanitary Engineer
Sewerage and Sewage Treatment
Water Supply and Purification
Industrial Wastes Disposal
Design, Construction, and Supervision of Operation
N. Front & Boas Sts. — Harrisburg, Penna.

WILLIAM A. GOFF, INC.
General Engineering and Consulting Services
Water, Sewerage, Refuse Incineration
Industrial Buildings, Power Plants
Airports, Town Planning
Plans, Supervision, Valuations, Reports
Broad St. Station Bldg., Philadelphia 3, Pa.

ONLY $60 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage works field and will afford maximum prestige!

GREELEY & HANSEN
Engineers
Samuel A. Greeley — Paul Hansen (1920–1944)
Paul E. Langdon — Kenneth V. Hill
Thomas M. Niles — Samuel M. Clarke
Water Supply, Water Purification
Sewerage, Sewage Treatment
Flood Control, Drainage, Refuse Disposal
220 S. State Street, Chicago 4

HAVENS AND EMERSON
Consulting Engineers
W. L. Havens — C. A. Emerson
A. A. Burger — F. C. Tolles — F. W. Jones
Water, Sewage, Garbage, Industrial Wastes, Valuations.—Laboratories
Leader Bldg., Cleveland 14 — Woolworth Bldg., New York 7

HAYDEN, HARDING & BUCHANAN
Consulting Engineers
John L. Hayden — John H. Harding
Oscar J. Campia
Water Works—Sewerage
Civil—Mechanical
Electrical—Structural
826 Park Square Building, Boston, Mass.

CHARLES HAYDOCK
Consulting Engineer
Water Works and Sanitation
Industrial Wastes
Design, Construction, Operation and Management
Reports and Valuations
2314 Girard Trust Co. Bldg., Phila. 2, Pa.

C. W. Durham — H. H. Henningson — W. A. Richardson
HENNINGSON ENGINEERING CO.
Consulting Engineers since 1917 for more than 600 cities and towns
Water Works, Light and Power, Sewers, Sewage Treatment, Reports, Flood Control, Appraisals, Drainage
Standard Oil Bldg. — Omaha 2, Nebraska

HITCHCOCK & ESTABROOK, INC.
Lester D. Lee, Associate
Consultants to Municipalities since 1920
WATER, SEWERAGE, PAVING, POWER PLANTS, AIRPORTS, PUBLIC BUILDINGS, SURVEYS and APPRAISALS
241 Sheridan Road, Menominee, Michigan — 521 Sexton Building, Minneapolis 15, Minnesota

Take advantage of the services of these outstanding consultants!

HORNER & SHIFRIN
Consulting Engineers
W. W. Horner S. W. Jens
H. Shifrin E. E. Bloss
V. C. Lischer
Airports — Hydraulic Engineering — Sewerage and Sewage Treatment — Water Supply — Municipal Engineering — Reports
Shell Building, St. Louis 3, Missouri

INDUSTRIAL WASTES CONSULTANTS
(A Guggenheim Subsidiary)
—INVESTIGATIONS AND REPORTS—
Offices and Laboratories
2266 No. Meridian, Indianapolis 8, Indiana
120 Broadway, New York 5, New York
Russell B. Moore—A. F. Nellson—Robert J. Theroux
(Memberships in ASCE, AWWA, AIMME, CSSWA, ACS)

JONES, HENRY & SCHOONMAKER
(Formerly Jones & Henry)
Consulting Sanitary Engineers
Water Works
Sewerage & Treatment
Waste Disposal
Security Bldg. Toledo 4, Ohio

KEIS & HOLROYD
Consulting Engineers
Formerly Solomon & Keis
Since 1906
Water Supply and Purification, Sewerage and Sewage Treatment, Garbage and Refuse Disposal and Incineration, Industrial Buildings.
TROY, N. Y. FT. LAUDERDALE, FLA

ENGINEERING OFFICE OF CLYDE C. KENNEDY
offers
COMPLETE ENGINEERING SERVICE
Investigations, Reports, Design, Supervision of Construction and Operation
Sewerage, Sewage Treatment and Industrial Waste Disposal
Chemical and Biological Laboratory
604 MISSION ST., SAN FRANCISCO 5

MORRIS KNOWLES, Inc.
Engineers
Water Supply and Purification, Sewerage and Sewage Disposal, Valuations, Laboratory, City Planning.
1312 Park Bldg. Pittsburgh 22, Pa.

Wm. S. Lozier Co.
Consulting Engineers
Sewerage, Sewage Disposal, Water Supply, Water Purification, Refuse Disposal
10 Gibbs Street Rochester 4, N. Y.

GEORGE B. MEBUS
Consulting Engineer
Water Supply Sewage Treatment
Industrial Waste Treatment
NORTHWESTERN NATIONAL BANK BUILDING
GLENSIDE, PA.

METCALF & EDDY
Engineers
Water, Sewage, Drainage, Refuse and Industrial Wastes Problems
Laboratory Valuations
Airfields
Statler Building 111 Sutter St.
Boston 16 San Francisco 4

Nussbaumer, Clarke & Velzy, Inc.
Consulting Engineers
SEWAGE TREATMENT—WATER SUPPLY
INCINERATION—DRAINAGE
INDUSTRIAL WASTE TREATMENT
APPRAISALS
327 Franklin St., Buffalo, N. Y.
52 Vanderbilt Ave., New York, N. Y.

Parsons, Brinckerhoff, Hall & Macdonald
G. Gale Dixon, Associate
Engineers
Dams, Water Works, Sewerage
Airports, Bridges, Tunnels
Traffic & Transportation Reports, Highways
Subways, Foundations, Harbor Works, Valuations
Power Developments Industrial Buildings
51 BROADWAY, NEW YORK 6, N. Y.

BOYD E. PHELPS, INC.
Architects and Engineers
Water Supply and Purification
Sewerage and Sewage Treatment
Power Plants, Buildings, Investigations, Reports, Appraisals, Rate Studies
Indianapolis and Michigan City, Indiana

It pays to secure competent and experienced engineering advice!

MALCOLM PIRNIE ENGINEERS
Civil & Sanitary Engineers
MALCOLM PIRNIE — ERNEST W. WHITLOCK
ROBERT W. SAWYER — G. G. WERNER, JR.
RICHARD HAZEN
Investigations, Reports, Plans
Supervision of Construction and Operations
Appraisals and Rates
25 W. 43rd St. New York 18, N. Y.

LEE T. PURCELL
Consulting Engineer
Water Supply & Purification; Sewerage & Sewage Disposal; Industrial Wastes; Investigations & Reports; Design; Supervision of Construction & Operation
Analytical Laboratories
1 Lee Place Paterson, 1, N. J.

THOMAS M. RIDDICK
Consulting Engineer and Chemist
Municipal and Industrial Water Purification, Sewage Treatment, Plant Supervision, Industrial Waste Treatment, Laboratories for Chemical and Bacteriological Analyses
369 E. 149th St. New York 55, N.Y.

RIPPLE AND HOWE
Consulting Engineers
O. J. RIPPLE — B. V. HOWE
Appraisals—Reports
Design—Supervision
Water Works Systems, Filtration and Softening Plants, Reservoirs and Dams, Sanitary and Storm Sewers, Sewage Treatment Plants, Refuse Disposal, Airports.
436 Cooper Bldg. Denver 2, Colorado

RUSSELL and AXON
Consulting Engineers
Geo. S. Russell
Joe Williamson, Jr. — F. E. Wenger
Sewerage, Sewage Disposal, Water Supply, Water Purification, Power Plants, Appraisals, Rate Investigations, Reports, Plans, Specifications.
408 Olive St. — Municipal Airport
St. Louis 2, Mo. — Daytona Beach, Fla.

SMITH and GILLESPIE
Consulting Engineers
All types of
Municipal Public Works &
Utilities
Complete Services
P. O. Box 1048, Jacksonville, Fla.

STANLEY ENGINEERING COMPANY
Sewerage—Waterworks
Drainage—Flood Control
Electric Power—Airports
Hershey Building
Muscatine, Ia.

Your firm should be listed here
. . . the most complete Directory available of consultants specializing in sewage and industrial wastes treatment.

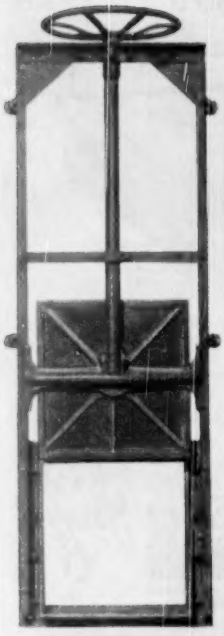
ALDEN E. STILSON & ASSOCIATES
Limited
Consulting Engineers
Water Supply—Sewerage—Waste Disposal
Mechanical — Structural
Surveys — Reports — Appraisals
209 S. High St. Columbus 15, Ohio

WESTON & SAMPSON
Consulting Engineers
Water Supply, Water Purification,
Corrosion Control
Sewerage, Sewage and Industrial
Wastes Treatment
Stream Pollution Studies
Supervision, Valuation
Laboratory
14 Beacon Street Boston 8, Mass.

WHITMAN & HOWARD
Engineers (Est. 1869)
Sewerage, Sewage Disposal, Municipal and Industrial Development Problems, Water Supply, Water Purification, Water Front Improvements, Investigations, Reports, Designs, Supervision, Valuations
89 Broad Street, Boston, Mass.

WHITMAN, REQUARDT & ASSOCIATES
Engineers—Consultants
Civil—Sanitary—Structural
Mechanical—Electrical
Reports, Plans, Supervision, Appraisals
1304 St. Paul Street Baltimore 2, Maryland

Take advantage of the services of these outstanding consultants!



SNOW GATES
for
SEWAGE TREATMENT PLANTS

All types of cast iron gates manufactured in either square or circular openings in sizes up to and including 72 inches.

ALL SNOW GATES and Lifts are "Parkerized" for protection against rust and corrosion.

Over 40 years continuous service to the industry.

We will be pleased to quote on any type of water controlling equipment.

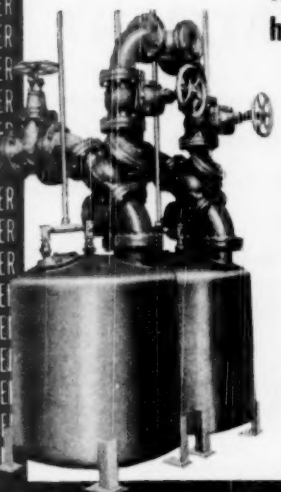
SNOW IRRIGATION SUPPLY CO.

2437 East 24th Street **Los Angeles 54, Calif.**

CARTER'S PNEUMATIC SEWAGE EJECTOR

for continuous, trouble-free, economical handling of sewage lift problems

CARTER
CARTER
CARTER
CARTER
CARTER
CARTER
CARTER
CAR
CARTER
CARTER
CARTER
CARTE
CARTE
CARTE
CARTE
CARTE
CART



For day-in-and-day-out 100% sewage boosting you can't afford not to consider Carter's pneumatic sewage ejectors. They practically pay for themselves by elimination of the costly auxiliary screening equipment required with centrifugal pumps.

Solids and trash up to the size of the inlet and discharge valves are easily handled. No moving parts—no clogging or binding. Pots are either copper bearing, electrically-welded steel or cast iron—to your specifications. Hermetically sealed—completely eliminate stuffing box leaks and toxic gas dangers. Bronze mounted double disc gates and swing check valves. Rotary type air compressors of high volumetric efficiency. Fully automatic controls. Capacities—30 to 250 GPM.

Exclusive franchises for representatives still open in some select territories. Write today!

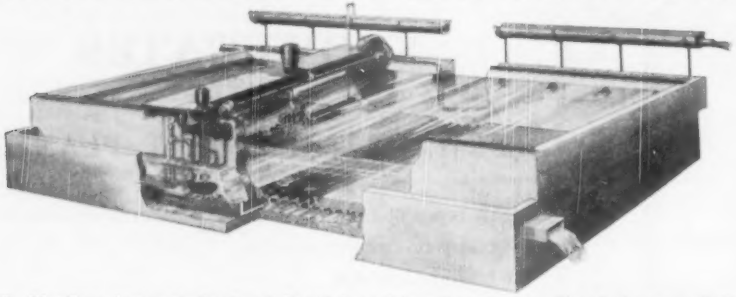
ROTARY DISTRIBUTORS • FLOATING & FIXED COVER DIGESTERS • ALTERNATING SIPHONS • PADDLE AERATORS • SLUDGE PUMPS • RAPID & SLOW MIXERS • PNEUMATIC EJECTORS • CIRCULAR COLLECTORS • FLOCCULATION EQUIPMENT • DIAPHRAGM PUMPS • SELF-PRIMING CENTRIFUGAL PUMPS • PLUNGER PRESSURE PUMPS

Write Dept. S—give your specific waste problems, and we'll promptly furnish a detailed reply.

184 Atlantic Street, Hackensack, N. J.

RALPH B. CARTER CO. HACKENSACK, NEW JERSEY

AUTOMATIC BACKWASH RAPID SAND FILTERS



The Hardinge Automatic Backwash Rapid Sand Filter cleans its own filter bed automatically, during operation. It runs at peak efficiency at all times without shutdown or change-over. It is extremely efficient in removing fine suspended matter not separable by sedimentation.

One 12′ x 88′ installation, handling 2200 gallons per minute of municipal water, reduced solids from 8.09 p.p.m. to 0.06 p.p.m.—99% removal.

Another 12′ x 40′ filter handling 750,000 gallons per day of paper mill "white water" reduced the suspended solids from 195 p.p.m. to 21.1 p.p.m. or 89% removal.

Write for Bulletin 46-16.

HARDINGE
COMPANY INCORPORATED

YORK, PENNSYLVANIA — 240 Arch St. • Main Office and Works
NEW YORK 17—122 E. 42nd St. • 205 W. Wacker Drive—CHICAGO 6
SAN FRANCISCO 11—24 California St. • 200 Bay St.—TORONTO 1

36 WORDS ABOUT 36 SEWAGE TREATMENT

The Bio-Chemical Process (a Guggenheim development) is a proved, economical, complete treatment of sewage—lowest first cost—lowest operating costs, utilizing community trade wastes to treat sewage.

Investigate this process without cost or obligation.

(If you counted only 36 words, you probably didn't realize that "economical" and "proved" are doubly important in connection with the Bio-Chemical Process)

THE BIO-CHEMICAL PROCESS

OFFICES AND LABORATORIES:

2266 N. Meridian, Indianapolis 8, Ind. • 120 Broadway, New York 5, N. Y.

Are You Interested in

Sewage and Industrial Waste Treatment?

If so, affiliate with

THE FEDERATION OF SEWAGE WORKS ASSOCIATIONS

•

For Particulars, Write

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

325 ILLINOIS BUILDING

CHAMPAIGN, ILL.

PROOF OF "STERELATOR EFFICIENCY"

NO JOB TOO LARGE

SEND US COPY OF SPECIFICATIONS

Actual Users—THE BEST PROOF OF ALL—Prove our claims that Everson SterElators are DEPENDABLE—SAFE—EFFICIENT Easy to operate at LOW MAINTENANCE COST.

Everson SterElators METER-MIX-FEED Chlorine gas accurately for all Water or Sewage Sterilizing demands

Furnished for Manual or Automatic operation.

Everson SterElators utilize a high Vacuum. The indicating FLOW METERS have a 10 to 1 ratio.

SterElators by Everson

EVERSON MANUFACTURING CORPORATION
207 West Huron Street, Chicago 10, Illinois

Please . . .

Copies of the following back numbers are badly needed:

1932—January, May
1934—January
1935—May, July
1944—January

Fifty cents plus postage will be paid for copies in good condition.

FEDERATION OF SEWAGE WORKS ASSNS.
325 Illinois Bldg. ◆ Champaign, Ill.

WHICH OF THESE BULLETINS DO *YOU* WANT—FOR LATEST FACTS ON RECORDING AND CONTROL INSTRUMENTS?

A. Pressure? Bulletin T835 describes Bristol Recording Gauges, Series 500, for measuring steam, water or gas pressure, from full vacuum to 10,000 psi.

B. Temperature? Bulletin T835 describes Bristol Recording Thermometers, Series 500, for measuring digester and dryer temperatures. Many new features.

C. Liquid Level? Bulletin L700 describes Bristol Liquid Level Recorders. Pressure, float and bubbler types.

D. pH? Bulletin pH1302 describes Bristol pH Controllers for treatment of sewage and industrial wastes.

Send coupon for bulletins you wish.

THE BRISTOL COMPANY
134 Bristol Road
Waterbury 20, Conn.
Please send bulletins circled.

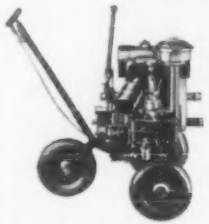
A B C D

Name_____
Company_____
Address_____
City_____ State_____

BRISTOL *a complete line for sewage works*

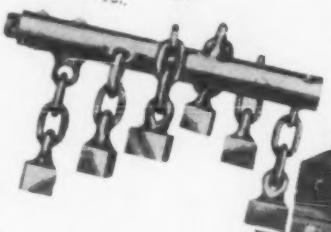
PIPE CLEANING TOOLS

FOR WATER LINES

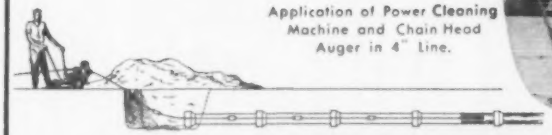


Above, "Flexible" Power Driven Pipe Cleaning Machine. Fast, Powerful, Safe.

Efficient Chain Head Cleaning Auger. A Power-Driven Tool.



Application of Power Cleaning Machine and Chain Head Auger in 4" Line.



FOR SEWER LINES

"Flexible" Carry-All Trailer, packs everything needed — Rod Reel, Steel Rods, Power Drive, etc.

...a few minutes ...rk for Dodge ...dy to get at the Root of the trouble with "Flexibles."

"FLEXIBLE"

UNDERGROUND PIPE CLEANING CO. — **SEWER-ROD EQUIPMENT CO.**

9059 VENICE BOULEVARD, LOS ANGELES 34, CALIFORNIA

141 W. Jackson Blvd. Chicago, Ill.
401 Broadway New York 13
147 Hillside Ter. Irving, N. J.
P. O. Box 165 Atlanta
P. O. Box 465 Memphis, Tenn.
801 E. Excelsoir Blvd. Hopkins, Minn.
29 Cerdan Ave. Roslindale 31, Mass.
Box 167 Los Nietos, Calif.
41 Greenway St. Hamden, Conn.
3786 Durango Ave. Los Angeles 34, Calif.
709 House Bldg. Pittsburgh 8, Pa.
4455 S. E. 24th Ave. Portland 2, Ore.
P. O. Box 447 Lancaster, Texas

INDEX TO ADVERTISERS

	Page
American Brass Company	6
American Well Works	19
Bio-Chemical Process	26
Bristol Company, The	22
Builders-Providence, Inc.	3
Carter Company, Ralph H.	25
Cast Iron Pipe Research Association	14
Chicago Pump Company	5
Crane Company	4
Dorr Company, The	18
Economy Pumps, Inc.	27
Everson Manufacturing Corporation	21
Flexible Sewer-Rod Equipment Company	20
General Chemical Division	23
Hamilton-Thomas Corporation	7
Hardinge Company, Inc.	24
Inertol Company, Inc.	12
Infilco, Inc.	9
Nordstrom Valve Division (Rockwell Manufacturing Company)	11
Pacific Flush Tank Company	17
Portland Cement Association	10
Snow Irrigation Supply	28
Rockwell Manufacturing Company	11
U. S. Pipe and Foundry Company	15
Wallace and Tiernan Company, Inc.	Back Cover
Yeomans Brothers Company	8

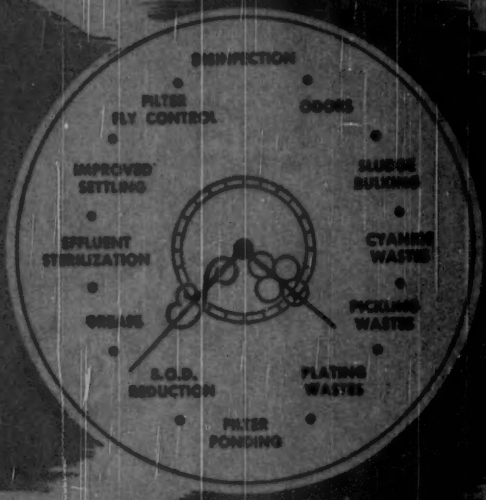
DIRECTORY OF ENGINEERS, pp. 30-34

Albright and Friel, Inc.
Alvord, Burdick & Howson
Baker, Jr., Inc., Michael
Baxter, Nelson & Woodman
Bets, W. H. & L. D.
Black and Veatch
Bogert, Clinton L., Associates
Bowe, Albertson & Associates
Buck, Seifert & Jost
Burgess & Niple
Burns & McDonnell Engineering Company
Camp, Dresser & McKee
Capitol Engineering Corporation
Chester Engineers, The
Conner, Townsend & Associates
Corson, Oscar
Damon & Foster
Dechant, Frederick H.
DeLeuw, Cather & Company
Fay, Spofford & Thorndike
Fulton, Edward A.
Gannett Fleming Corddry & Carpenter, Inc.
Gilbert Associates, Inc.
Glace, Ivan M.
Goll, Inc., William A.
Greeley & Hansen
Havens and Emerson
Hayden, Harding & Buchanan
Haydock, Charles
Hazelhurst Engineering Company
Hitchcock & Fitzimmons, Inc.
Horner & Shifrin
Industrial Waste Consultants
Jones, Henry & Wesson
Kale & Bishopp
Kennedy, Clyde C.
Knowles, Inc., Morris
Lozier, William S., Company
Melvin, George B.
Metcalf & Eddy
Numbauser, Clarke & Velzy, Inc.
Parsons, Brinckerhoff, Hall & MacDonald
Phelps, Inc., Boyd E.
Pirnie Engineers, Malcolm
Purcell, Lee T.
Rabbit, Thomas M.
Ripple and Howe
Russell and Axon
Smith & Gillespie
Stanley Engineering Company
Stilson & Associates, Alden E.
Weston & Sampson
Whitman & Howard
Whitman, Requardt & Associates

PATRONIZE OUR ADVERTISERS—whose support makes possible the publication of this Journal. *When writing advertisers be sure to mention SEWAGE AND INDUSTRIAL WASTES.*

LANCASTER PRESS, INC., LANCASTER, PA.

It's always time for CHLORINATION



W & T SEWAGE CHLORINATOR

Chlorination time at a modern sewage treatment plant knows no hour or season — it's always the right time to use this versatile tool in the solution of the numerous problems the average operator faces every day. For example, chlorination *controls odors* at Fort Wayne, Indiana; reduces *filter ponding* at Rotterdam, New York; and *sterilizes the effluent* of the Easterly Sewage Plant at Cleveland, Ohio.

Best of all, the advantages of chlorination aren't expensive. The average installation represents less than 1% of total plant cost.

Why not make it "chlorination time" in your plant now. Call your nearest W&T Representative for the benefit of over 35 years' experience in chlorination, a full line of equipment for every sewage plant need, the practical knowledge gained in making thousands of installations, and the availability of a nationwide service staff.

S-80

WALLACE & TIERNAN COMPANY, INC.